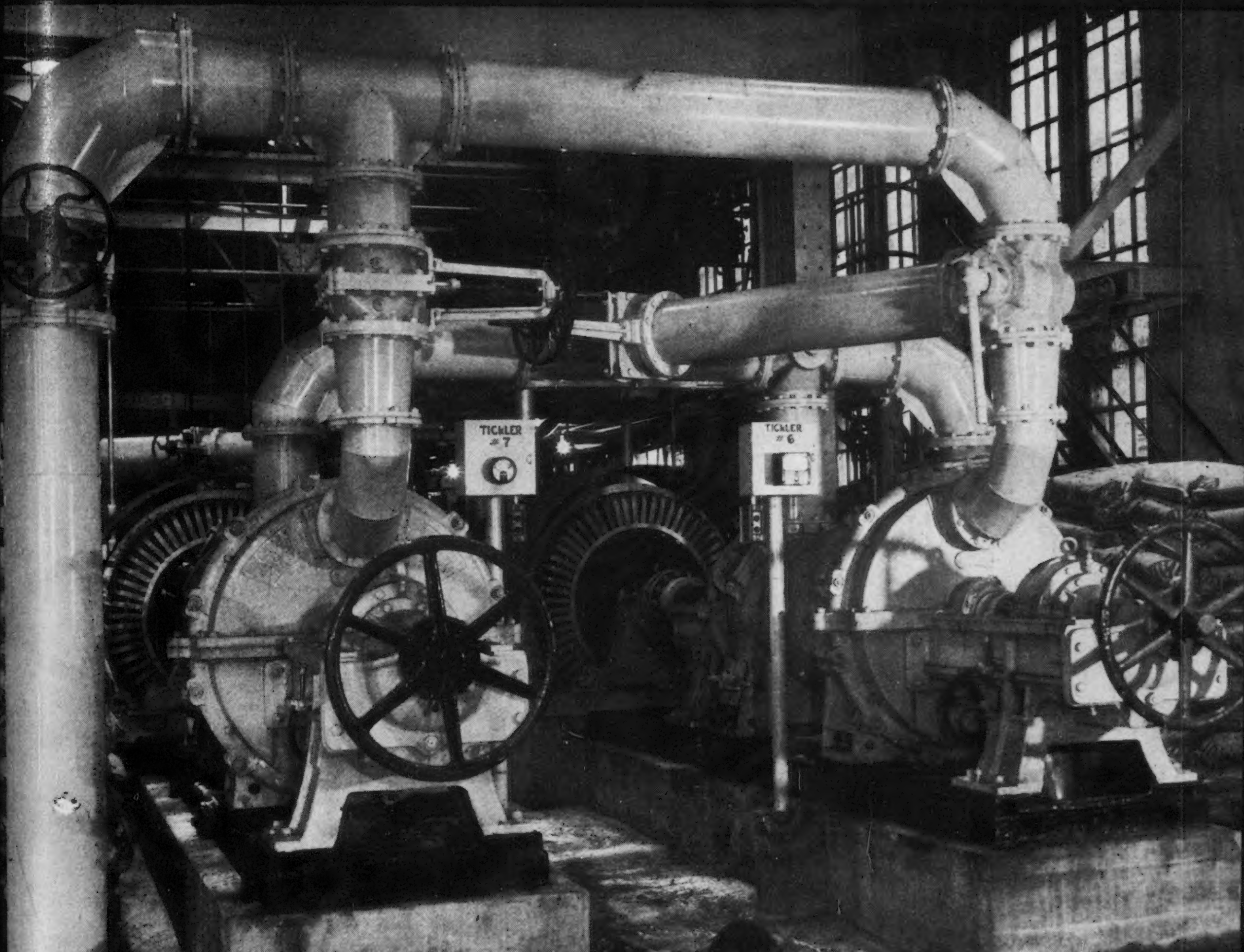
Corrosion

Official Publication
NATIONAL ASSOCIATION OF CORROSION ENGINEERS



NOVEMBER, 1951 No. 11

CORROSION CRIPPLES-
MORE WAYS THAN ONE

Valuable products as well as vital equipment are threatened

Corrosion takes its toll in more ways than one—it eats away costly, hard-to-get equipment—wastes man-hours while plants are shut down for repairs—and causes loss of vitally-needed products through contamination.

Every industry suffers from corrosion in some form, yet much of this waste can be avoided by taking these steps:

1. Check manufacturing equipment, storage tanks, and other items exposed to corrosive fumes, acids, alkalies, or moisture.
2. Arrange to protect them with AMERCOAT — the corrosion resistant coatings, each built to conquer specific industrial corrosion problems.

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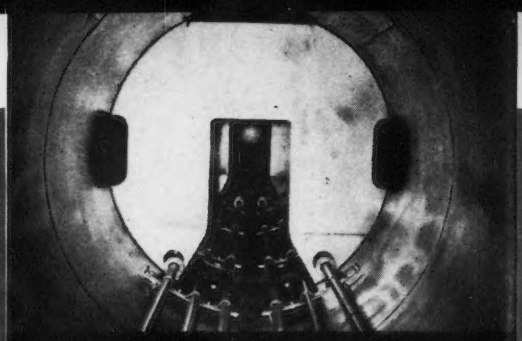
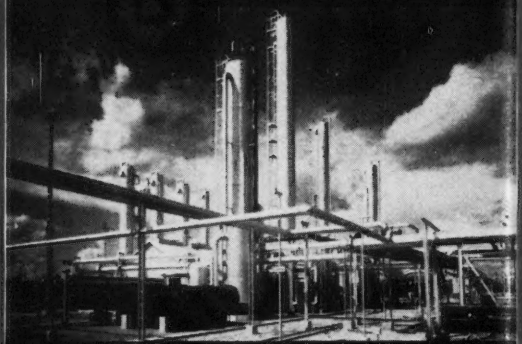
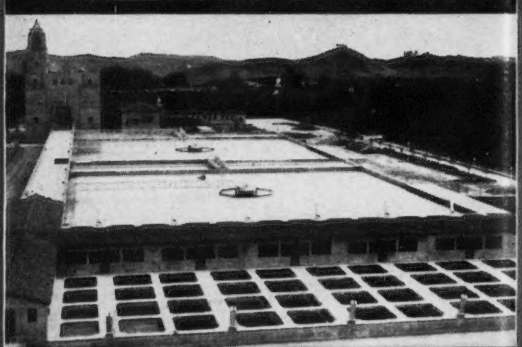


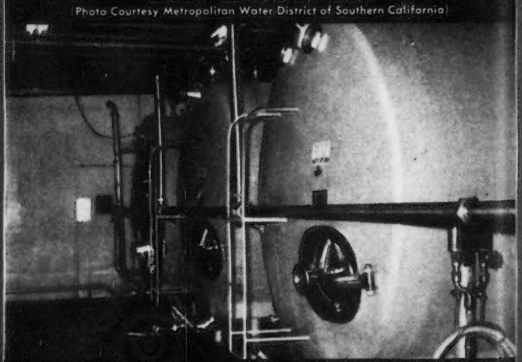
CHEMICAL PLANTS — Caustic Soda Tank



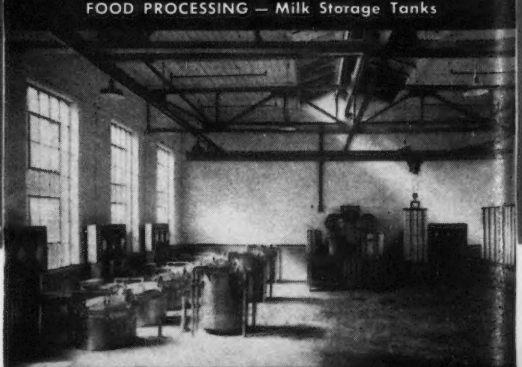
PETROLEUM REFINING — Columns and Piping

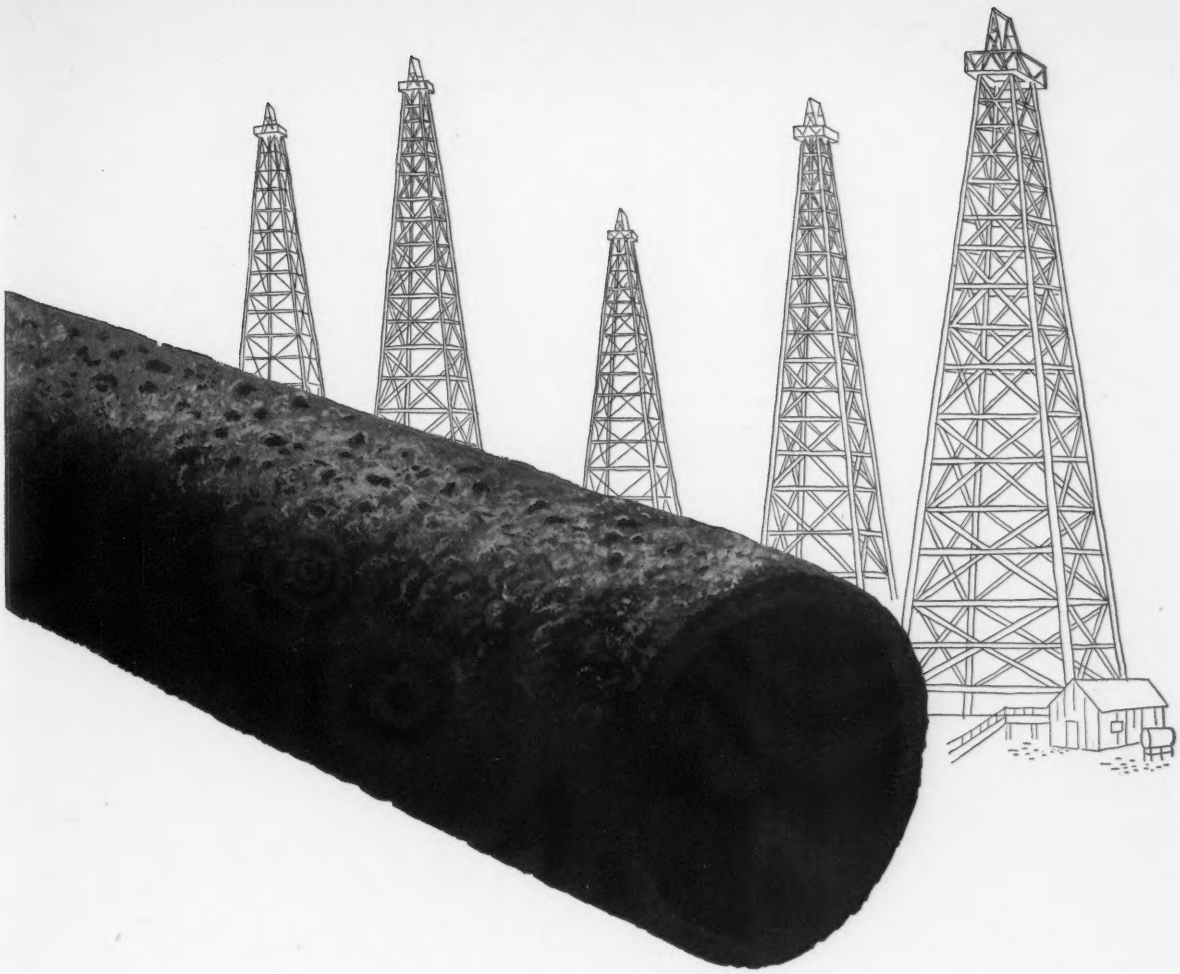


WATER SOFTENING PLANT
Photo Courtesy Metropolitan Water District of Southern California



FOOD PROCESSING — Milk Storage Tanks





Here Are Some Facts On CORROSION INSURANCE

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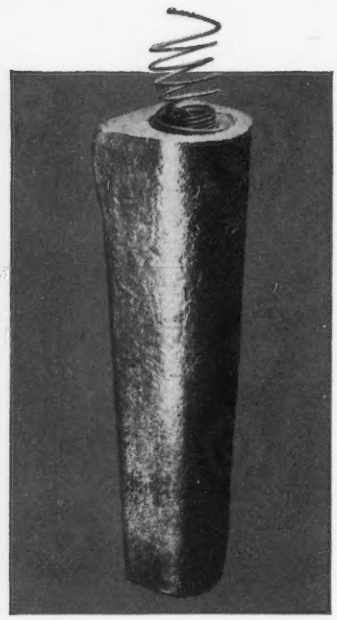

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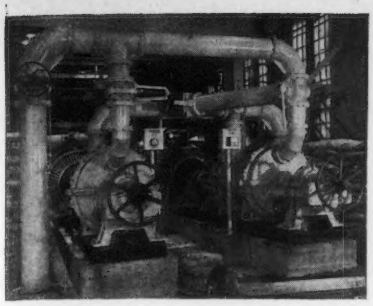

THIS MONTH'S COVER—This installation carrying chlorine-bleached pulp stock includes wood-lined pipe manufactured by the Michigan Pipe Company, Bay City, Mich. The pulp is carried from pulp beaters into and away from the two Jordan refiners (illustrated). The piping material must be inherently resistant to corrosion by bleached pulp, sized pulp or pulps high in tannic acid. The wood-lined pipe and fittings used here keep the pulp free of iron contamination.

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Corrosion

devoted entirely to **CORROSION** *research and control*

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VOL. 7 NOVEMBER, 1951 NO. 11

CONTENTS

	Page
Directory of NACE Regional and Sectional Officers	iv, v
Technical Material Scheduled for Publication December	v
Directory of Technical Practices Committees	x
Officers and Directors, National Association of Corrosion Engineers	xiv
TECHNICAL SECTION	
Selling Management on Corrosion Control *By H. H. Anderson*	361
Area Effects in Crevice Corrosion *By O. B. Ellis and F. L. LaQue*	362
Effect of Packaging on Corrosion of Zinc Plated Equipment *By K. G. Compton, S. M. Arnold and A. Mendizza*	365
Historic Church's Copper Roof Good After 213 Years *By A. W. Tracy*	373
Performance of a Comprehensive Group of Coatings on Steel. First Interim Report, Immersion and Atmospheric Exposures 1949 —, United States Panama Canal Protective Coatings Investigation *By H. W. Mundt and L. J. Thompson*	376
Prevention of Corrosion in Naval Aircraft. Part II of Two Parts *By N. E. Promisel and G. S. Mustin* Discussion: Marc Darrin, George E. Best, Page 388; H. A. Robinson, Otto E. Kirchner, Page 389	377
Control of Sour Crude Corrosion in Kansas Production Operations *By L. C. Case* Discussion: H. E. Waldrip, J. N. Breston, H. C. Spalding, Page 396	390
Corrosion Inhibition in Gas Condensate Wells By Intermittent Injection of Alkaline Solutions *By Charles C. Nathan*	397
DISCUSSIONS	
Stress Corrosion Cracking in Alkaline Solutions *Thomas F. Degnan, John L. McPherson, Leon D. Cook, Jr., Clifford B. Armstrong, Jr., C. S. Landau, Jr., James B. Horton, M. A. Scheil*	400
The Passivating Characteristics of the Stainless Steels *F. L. LaQue, H. H. Uhlig, H. W. Schmidt, Garland M. Riegel, L. M. Nieliwocki, Roy V. Comeaux*	400
Rosin Amine-Ethylene Oxide Condensates as Corrosion Inhibitors for Mild Steel in Hydrochloric Acid *C. S. Brown, Charles M. Blair*	403
Current Requirements for the Cathodic Protection of Steel in Dilute Aqueous Solutions *S. C. Britton*	403
Dicyclohexylammonium Nitrite, a Volatile Inhibitor for Corrosion Preventive Packaging *Louis M. Nieliwocki, James E. Shields, Marc Darrin*	404
Cathodic Protection of An Active Ship in Sea Water—Part II *E. C. Reichard, P. M. Aitken and G. L. Christie*	405

NACE REGIONAL AND SECTIONAL NEWS

	Page		Page
Sam Tour, W. E. Pratt Discuss Testing at Metropolitan New York Section Meeting	3	Fontana Addresses North Texas Section Meeting	4
Silica Gel Is Baltimore Topic	3	Corpus Christi Barbecue	4
Goodrich Tour Feature at Cleveland	3	Short Course Discussed at Shreveport Meeting	4
Philadelphia Section	4	Plastic and Concrete Linings, Inhibitors for Pipe Lines Discussed at Houston	5
Chicago Sees Pipe Line Movie	3	South Central Region Meets	8
Formation of Boston Section Seen	3	Permian Basin Tour Attracts Many	10
Fontana Addresses E. Wisconsin	3	Pittsburgh Hears Mears	12
Sabine-Neches Section Hears Fontana	3	8 Papers, Forum Set at Los Angeles	12
Detroit Section Sees Need for Energetic Attack on Corrosion	4	Failure of Stainless Tubes Is Topic at San Francisco	12
Corrosion by Acids Emphasized at Houston Section Meeting	4	Cogshall Recalled by Navy	26
Index to General News of Corrosion Interest			14
Index to Corrosion Abstracts			29
Index to Advertisers			49

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DECEMBER

A Proposed Alternative Method for Measuring the Electrical Resistance of Pipe Line Coatings
By J. K. Ballou, R. P. Howell, J. W. Liljeberg and P. F. Offermann

The Mechanism of Scale Formation at High Temperatures
By B. W. Dunnington, F. H. Beck and M. G. Fontana

Potential Measurements for Determining Cathodic Protection Requirements
By Scott P. Ewing

Sodium Hydroxide as an Inhibitor of Pitting In 18-8 Stainless Steel
By J. W. Matthew and H. H. Uhlig

Corrosion Aspects of Fusion Welding Aircraft High Strength Aluminum Alloys
By L. W. Smith

TOPIC OF THE MONTH—Versatile Electric Arc Metal Spraying Pistol Has High Potential

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Persons interested in submitting material for publication are invited to write for "Guide for Preparation and Presentation of Papers," which gives complete information on the requirements of the association.

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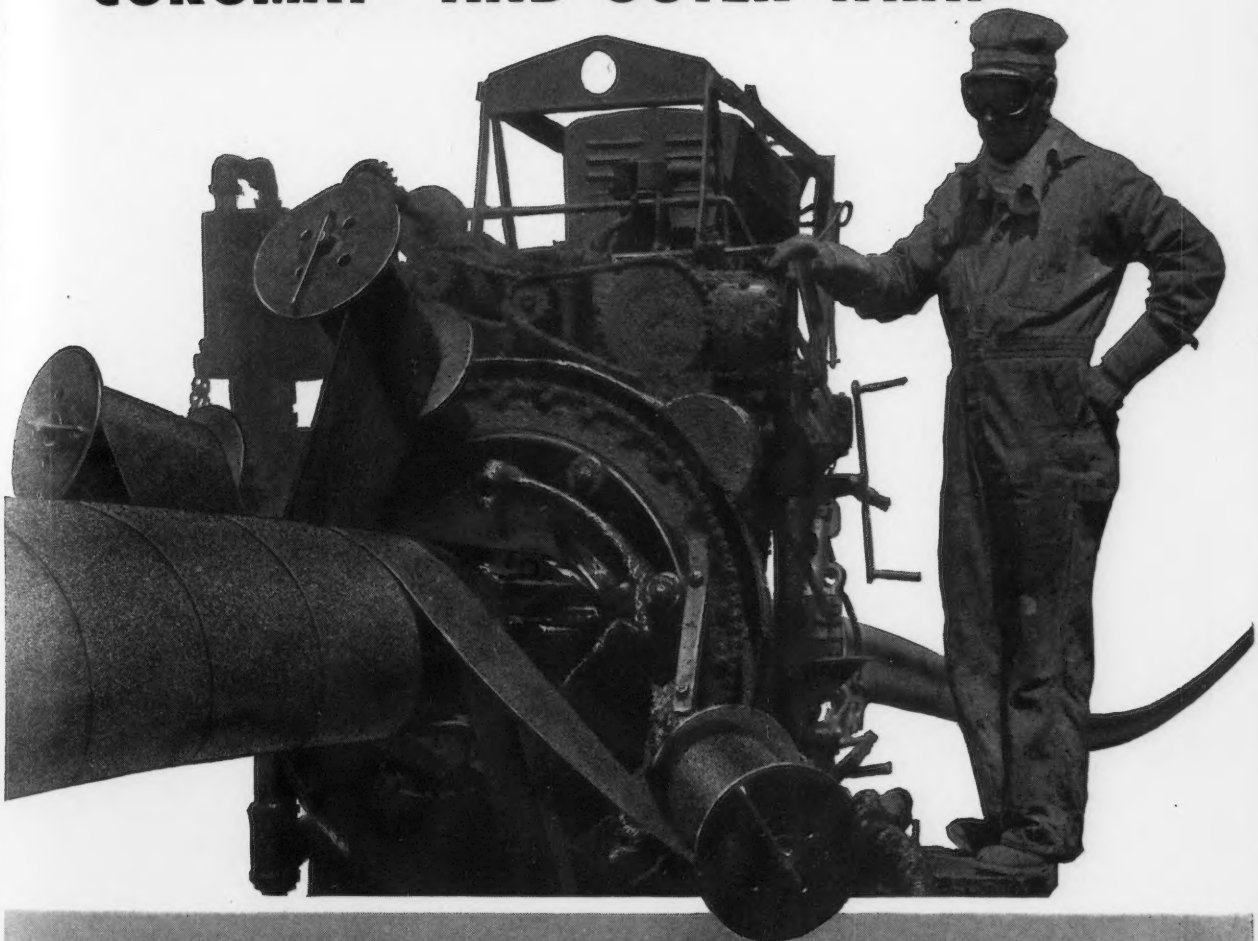
5. Retains full strength under hot application.
6. Longer rolls and virtually no breaks give more miles wrapped per day.

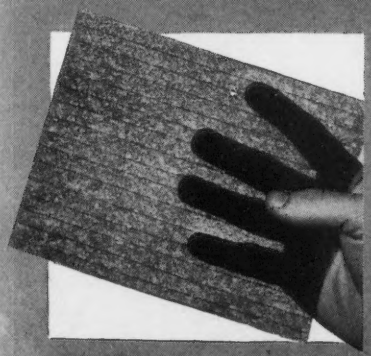
*Fiberglas (Reg. U. S. Pat. Off.) and COROMAT are trade-marks of Owens-Corning Fiberglas Corporation for products made of or with fibers of glass.

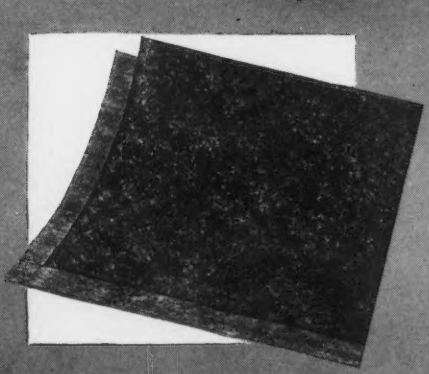
1/3 faster

COROMAT* AND OUTER WRAP

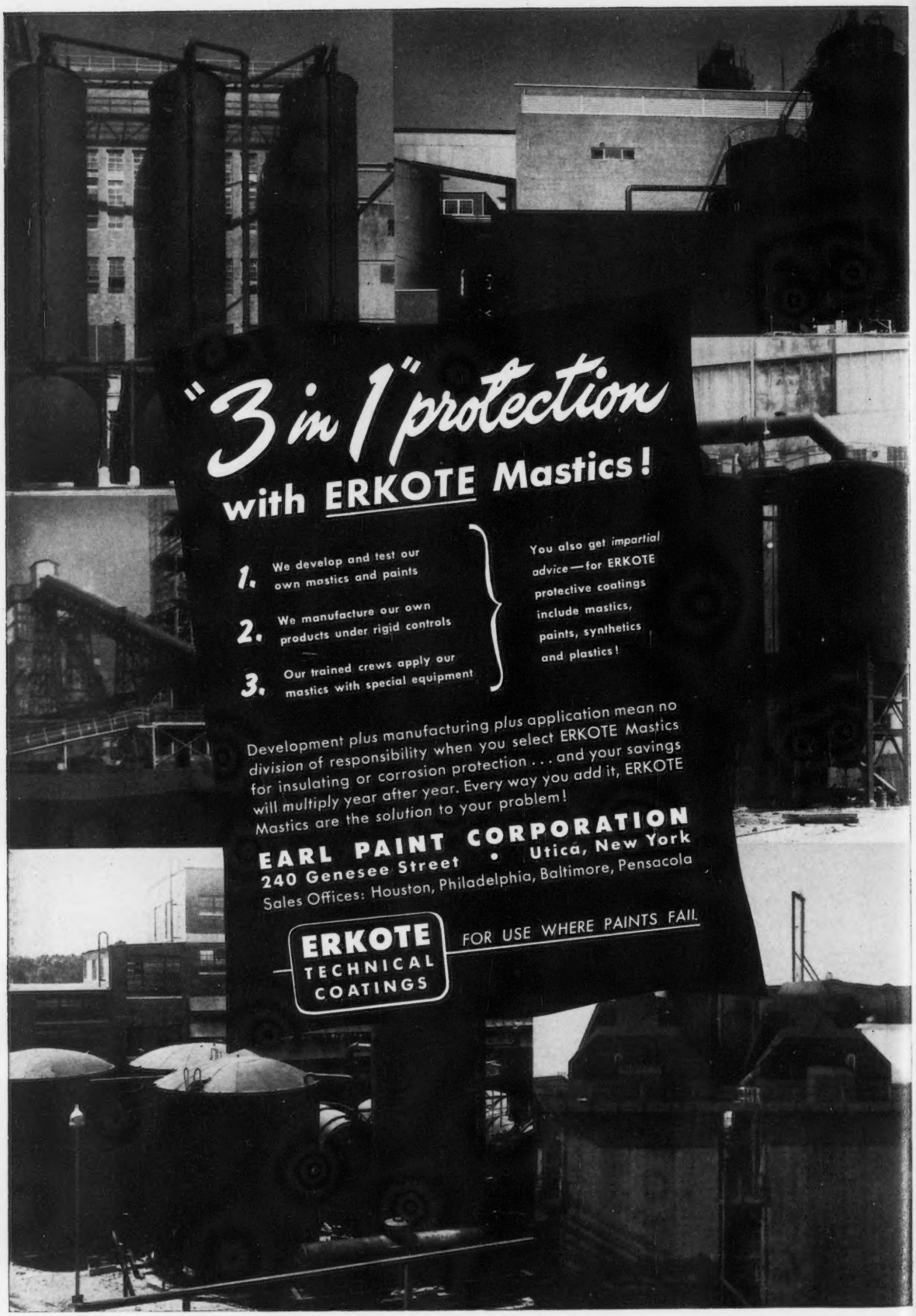


Protect the corrosion protection with Fiberglas OUTER WRAP!





1. Exclusive glass-and-bitumen construction cushions backfill impact, soil stresses, bumps.
2. Strong, reinforced COROMAT core permits fast, break-free wrapping.
3. Porosity releases trapped gases, permits keying enamel to outer wrap, minimizes holidays.
4. No wicking action to absorb moisture or draw off rich protective oils.
5. Applies snugly around any bend a wrapping machine can travel.
6. No moisture pickup during storage or application.
7. Reflective surface helps enamel to set up faster in hot weather.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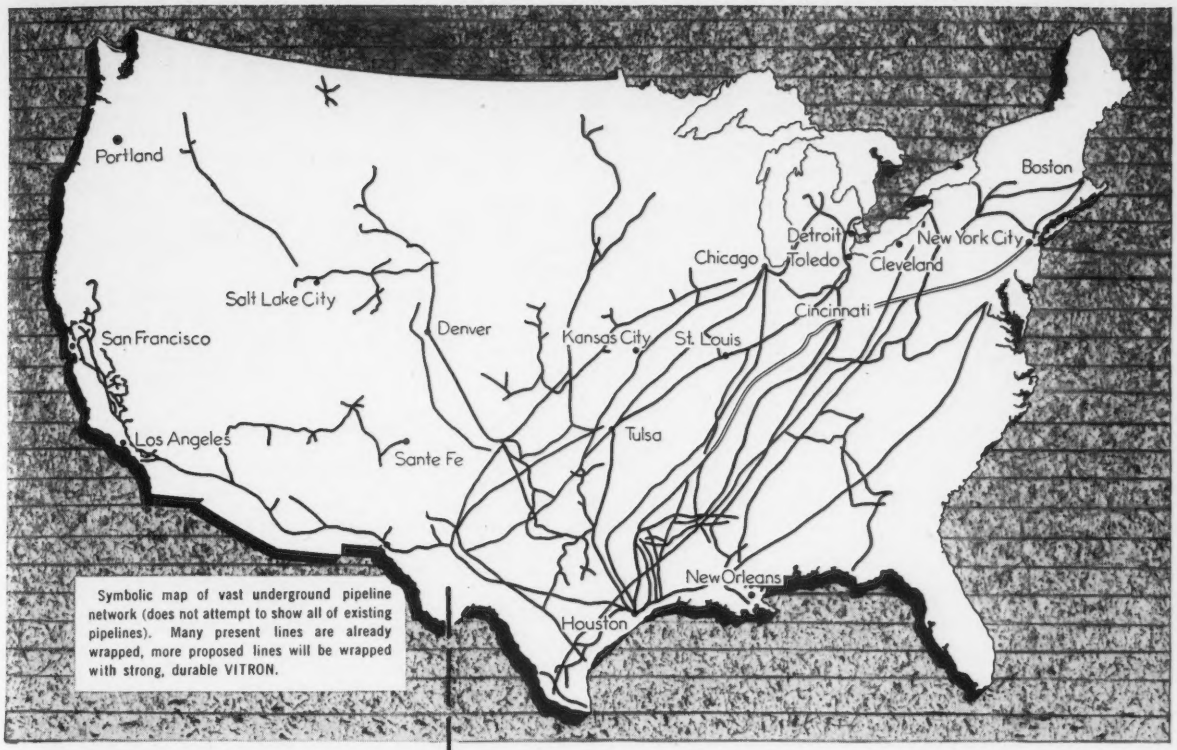

Symbolic map of vast underground pipeline network (does not attempt to show all of existing pipelines). Many present lines are already wrapped, more proposed lines will be wrapped with strong, durable VITRON.

The vital role of *Vitron* glass fibers in the nation's pipelines

VITRON Underground Pipe Wrap gives longer life to steel pipelines

Right beneath our feet—beneath the broad fields of America—a high speed, mass-volume transportation system is quietly and economically carrying the nation's oil and gas from well to refinery and distribution center. VITRON Underground Pipe Wrap is a vital factor in the long-life expectancy of these history-making steel pipelines.

Applied by high speed coating and wrapping machines, the highly porous VITRON Wrap pulls into the hot coatings, providing strong, durable reinforcement. Coating "bleed through" forms a continuous film, and air and vapor bubbles that can form "holidays" are cut up and reduced by the porous wrap. VITRON-reinforced coatings have greatly increased resistance to impact, soil stresses, moisture and soil acids.

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TYGON

Versus HNO_3

NITRIC acid on the attack is hard to stop. However, there are good defenses available and one of the best is the versatile group of TYGON plastic compounds. Properly used, TYGON—as tank lining, gasketing, flexible piping, or protective coating—displays excellent resistance to nitric acid over a useful range of concentrations and conditions.

Essentially, TYGON consists of selected polyvinyl resins skilfully modified with other materials to give the optimum in chemical resistance and desirable physical properties. Solid TYGON is available in calendered, extruded, or molded form. Liquid TYGON is available as a plastisol or as a solvent type paint. Such variety in form permits the best use of TYGON for a specific application.

In calendered form, TYGON is generally used as a material of construction. Volume use is as a lining for tanks and tank covers, drums, hoppers, fume hoods, and fume ducts. Widest use is as cut gaskets and washers for sure, durable seals in all types of chemical process equipment. As a 3/32" calendered sheet, TYGON resists nitric acid in concentrations up to 30% by weight and temperatures as high as 150°F. Permissible concentration depends upon the temperature of service, with only the lower strength solutions being advised for the higher temperature. When cut into gaskets, calendered TYGON can be used with practically any concentration of the acid as the slight swelling and other changes that take place in the small exposed area serve only to make a tighter seal and have very little effect on the protectability or functioning of the entire gasket. Either as sheet or gasket, TYGON is not recommended for service with mixed or nitrating acids without previous consultation with U. S. Stoneware engineers.

In extruded form, TYGON is used primarily as a medium of transmission. However, extruded solid cord, channel, or tape are also used as materials of construction.

Smooth walled, light weight and flexible, TYGON Tubing, in sizes up to 2" ID, is used in a great number of laboratories and plants for the safe, efficient transmission of liquids, gases and semi-solids. In many plants, TYGON is being used as flexible piping in permanent or temporary transfer lines, as flexible connections, as line desurgers, as ports on chemical pumps and filters, or as syphon hoses.

As tubing, TYGON is resistant to nitric acid in any concentration and at temperatures up to 130°F. For brief, intermittent exposures, the temperature limit can be increased to 150°F. However, in any service with nitric acid, the life of TYGON Tubing is directly dependent upon the length of exposure and the care given the tubing. Short periods of service and frequent cleanings are suggested. The counsel of our engineers is recommended.

In molded form, TYGON sees service as gaskets, grommets, washers, stoppers, handles, bumpers and special fittings. Where necessary, it can be reinforced with glass fibers for added strength. With or without reinforcement, molded TYGON generally is suitable for service with nitric acid of any concentration and temperatures as high as 150°F. Specific limitations depend upon the size and design of the piece, the temperatures and pressures involved, and other conditions of service. Use with mixed or nitrating acids is not advised without consultation.

As a paint, TYGON, in contact with nitric acid, must be considered in the light of the limits of a thin film. Generally, a TYGON paint film is resistant to the fumes of nitric acid in all concentrations and up to 150°F. However, contact with highly concentrated hot nitric acid is to be avoided and any spillage, regardless of concentration, should immediately be washed off. The minimum system recommended for any service with nitric acid consists of a primer and no less than five top coats.

As a plastisol, TYGON finds use as a heavy duty coating and in the casting or "slush" molding of flexible fittings and parts. For coating work, it can be applied by dipping or spraying on hot metal, and, then, fusing. Resistance to nitric acid varies, depending upon the thickness of the coating deposited.

In any of its forms, TYGON provides low cost protection and high degree of safety in the handling of not only nitric acid and related chemicals, but a wide range of other acids, alkalies, oil, greases and water.

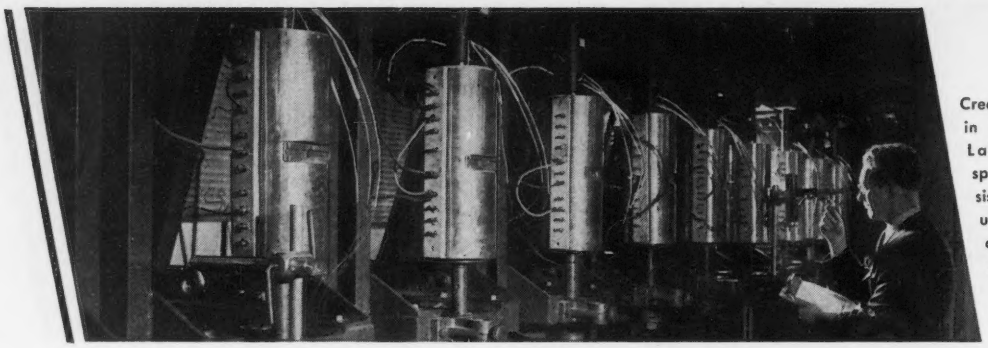
TYGON plastics

In addition to TYGON in its various forms, we also manufacture a number of other materials capable of handling nitric acid in any concentration and under all types of operating conditions. These products include chemical stoneware and porcelain, acid proof brick and cements, and other organic linings and coatings.

Why don't you submit your corrosion problem, today? There's no obligation and we'll be pleased to be of assistance. So write, now! 223c

THE UNITED STATES STONEWARE CO., Akron 9, Ohio

ENGINEERS, MANUFACTURERS, ERECTORS OF CORROSION-RESISTANT EQUIPMENT SINCE 1865



Creep tests under way in INCO's Research Laboratory. Here specimens of heat-resisting alloys are held under constant load at temperatures up to 2100°F.

IS HIGH-TEMPERATURE PERFORMANCE YOUR PROBLEM?

INCO Engineers may have the answer...

Your *successful* selection of metals for high-temperature operations often requires more than a simple evaluation of mechanical properties of the material itself.

The most important factor may be a specific corrosive condition linked to the elevated temperature-environment—a trouble not apparent, perhaps, at moderate thermal levels. And as the trend to higher operating temperatures develops, new high-temperature corrosion problems follow.

Engineers who encounter high-temperature problems in their work with design, production, and operations may find Inco High-Temperature Engineering Service a valuable source of information.

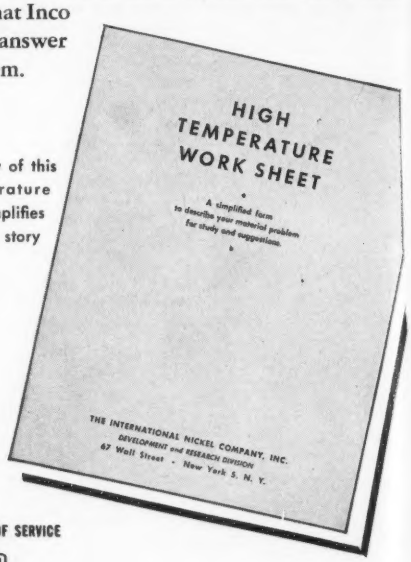
INCO'S HIGH-TEMPERATURE ENGINEERING SERVICE

As industry progressed, it used higher temperatures and required metals and alloys to withstand these temperatures. Inco Engineers have endeavored to assist by analyzing the requirements and furnishing experimental data for the selection of the material.

Inco laboratory facilities at Bayonne, N. J., and Huntington, W. Va., have assembled data on mechanical properties of metals at high temperatures... and performance under corrosive conditions. Constant research is adding to this fund of information. Inco Engineers in the field are learning of conditions that cause unsatisfactory performance and how best to remedy them.

In a field that grows so fast, it is obviously impossible to have an immediate answer to every problem. But each new problem solved or studied adds to the total of knowledge on the subject. So if *you* are having high-temperature problems – whether in an existing application or with a new project, let the Inco Engineers work with you. Send for our High-Temperature Work Sheet, a simplified form to set out your full story. And you may find that Inco can suggest an answer to your problem.

Send for your copy of this new High-Temperature Work Sheet; it simplifies gathering the full story of your problem.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A simplified form to describe your material problem for study and suggestions.
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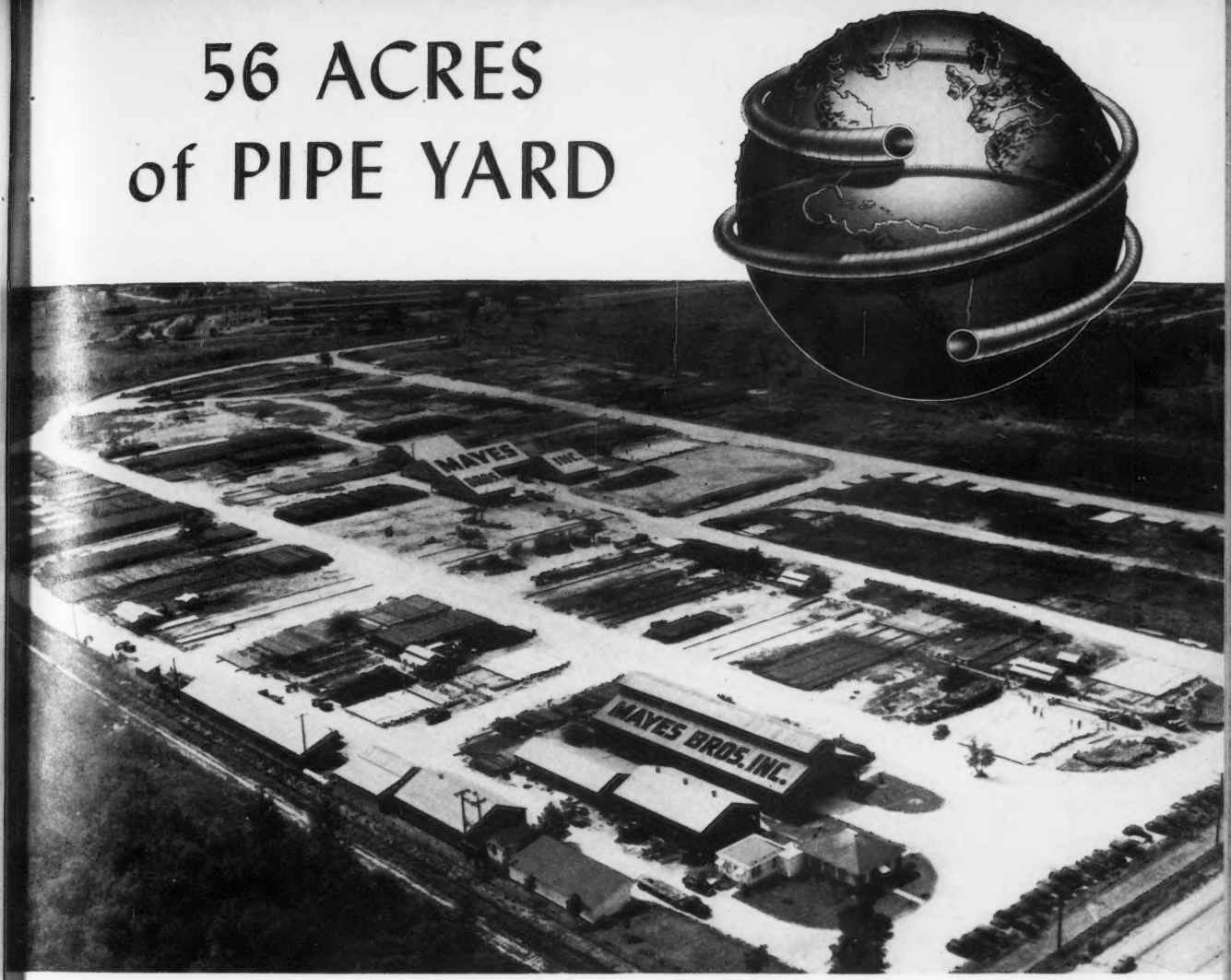
56 ACRES of PIPE YARD



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"PUTTING *Permanence* IN PIPE"

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THE NATIONAL ASSOCIATION OF CORROSION ENGINEERS

is a non-profit, scientific and research association of individuals and companies concerned with corrosion or interested in it, whose objects are:

(a) To promote the prevention of corrosion, thereby curtailing economic waste and conserving natural resources.

(b) To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.

(c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.

(d) To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.

(e) To promote standardization of terminology, techniques, equipment and design in corrosion control.

(f) To contribute to industrial and public safety by promoting the prevention of corrosion as a cause of accidents.

(g) To foster cooperation between individual operators of metallic plant and structures in the joint solution of common corrosion problems.

(h) To invite a wide diversity of membership, thereby insuring reciprocal benefits between industries and governmental groups as well as between individuals and corporations.

It is an incorporated association without capital stock, chartered under the laws of Texas. Its affairs are governed by a Board of Directors, elected by the general membership. Officers and elected directors are nominated by a nominating committee in accordance with the articles of organization. Election is by the membership.

Inquiries regarding membership, and all general correspondence should be directed to the Executive Secretary at the administrative headquarters of the National Association of Corrosion Engineers at 919 Milam Building, 803 Texas Avenue, Houston 2, Texas.

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Corrosion

OFFICIAL MONTHLY PUBLICATION

National Association of Corrosion Engineers

An Association of Individuals and Organizations Concerned with Control of Corrosion

919 Milam Bldg. Houston 2, Texas

Vol. 7 November, 1951 No. 11

Selling Management on Corrosion Control

By H. H. ANDERSON

Chairman, Membership Control Committee

National Association of Corrosion Engineers

THE WORD "NATURAL" is defined as "a thing that is by nature notably satisfactory." Seldom do we find such a *natural* for promotion as "control of corrosion."As in the promotion of safety, everybody benefits by the promotion of corrosion control.

The nation's present bill for corrosion is estimated to be about 5½ billion dollars per annum, which "isn't peanuts." It represents, in fact, a serious loss to our national economy and a direct loss to each company that operates substantial tonnages of metallic plant.

How does everybody benefit from control of corrosion? The public benefits by not having eventually to pay corrosion costs. The operating companies benefit by not having to include such costs in charges for products, utilities and services. Suppliers of corrosion preventives benefit by the fair profit they can make from a legitimate business. Corrosion engineers benefit by continued gainful and respected employment. And NACE benefits by continuing as the recognized forum to spearhead a great utilitarian program.

You perhaps have been told that industry abhors a salesman who poses as an engineer, or an engineer who poses as a salesman. But when it comes to control of corrosion—a thing so technical that it still baffles many of our alleged experts—we cannot expect Management to fully appreciate its value unless each engineer "goes all-out" to explain and sell it to his boss.

It is proper also that he should sell his boss—and keep him sold—on the need to support NACE. His boss should be made aware that maintenance of the camaraderie afforded us by NACE is the only way corrosion engineers can effectively pool their experience and inspiration to meet the great opportunity, challenge and obligation that confront them in corrosion control.

It behooves every NACE member thus to become a salesman for corrosion control *and for NACE*. Each one should do his utmost to gain more active members for the Association and to induce his own employer to join as a corporate member so as to insure the Association the financial support it needs and merits.

A few days ago President Berry appointed H. L. Bilhartz of Atlantic Refining Company in Dallas to become Vice Chairman of the Membership Control Committee. Mr. Bilhartz will especially deal with the solicitation of active members. This will complement the effort of the writer in soliciting corporate members, 43 of which have joined since February, 1951.

Area Effects in Crevice Corrosion*

By O. B. ELLIS and F. L. LaQUE

IN ENVIRONMENTS capable of breaking down the passivity of metals, it is common for accelerated corrosion to occur within any crevices into which the corrosive medium may seep. This subject was discussed in some detail in an earlier paper by one of the present authors and his associates.[1]

Such observations have tended to make users of susceptible alloys fearful of severe crevice corrosion wherever a crevice may exist. However, as with other forms of electrochemical attack, a distinction must be made between the chance or incidence of crevice corrosion and the intensity of the attack when it does occur.

There is a good foundation for the belief (supported by the data to be offered here) that the mechanism of crevice corrosion involves electrochemical action between the surfaces within the crevices and those freely exposed to the environment outside it. In the simplest case, this would be a differential aeration or oxygen concentration cell effect with the metal within the crevice shielded from free access to dissolved oxygen becoming anodic to the outside surfaces freely exposed to the oxygen bearing solution.

With stainless steels and other metals or alloys that resist corrosion as a result of the favorable influence of dissolved oxygen or other oxidizing media, and which, likewise, exhibit a more noble potential when in this passive state, the matter becomes complicated and aggravated by the active: passive galvanic cells that may become established. The metal within the crevice shielded from oxygen may become active while that outside in free contact with oxygen will have its passivity preserved. The difference in potential between the active and passive states will become a driving force in the galvanic corrosion of the anode within the crevice.

It can be assumed, therefore, that the crevice corrosion of a passive metal is simply a particular kind of galvanic cell with the anode being the active metal within the crevice and the cathode the passive metal outside it. This being the case, the action of this cell should obey the rules of other galvanic cells. In particular, in environments where the galvanic cell reaction is under cathodic control (e.g. where the supply of oxygen to depolarize the cathodes has a controlling effect) the extent of corrosion of the anodes within the crevices should be determined principally by the area of the freely exposed surfaces (the cathodes) outside the crevices in accordance with the "Catchment Area Principle" based on the experiment by Whitman and Russell[2] with couples of steel and copper in water. It would follow, then, that corrosion in crevices should be most serious where the area of freely exposed metal outside is relatively large and least serious under circumstances where the area outside the crevice is relatively small and perhaps even non-existent where the area outside the crevice is zero — as would be the case with a continuous crevice such as would exist where only the metal within the crevice would be exposed to the corrosive liquid.

It occurred to the authors that these principles and their indications might be checked by exposing specimens of stainless steel to corrosion in sea water.

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Abstract

Specimens of stainless steel were prepared to provide an experimental approximation of a crevice relatively small with reference to the area outside exposed to the corrosive. Test panels were exposed to running fresh sea water for 87 days.

Data secured confirmed the expectations the extent of attack within a crevice was proportional to the area of the freely exposed metal outside. This means greatest danger exists when a crevice is associated with a large area of freely exposed metal and that when area of metal outside a crevice approaches zero the extent of corrosion within a crevice also will approach zero and will be determined only by the access of the corrosive medium and oxygen to surfaces within crevice.

The mechanism of crevice corrosion involving a metal ion concentration cell is substantially the reverse of that postulated in the experiment conducted.

The alloy and the environment are appropriate to illustrate the principles since crevice corrosion of stainless steel in sea water can be expected to occur if the conditions of exposure are chosen properly.

Specimens of the design shown by the drawing in Figure 1, and illustrated in Figure 1A, were prepared in the Research Laboratories of the Armco Steel Corporation at Middletown, Ohio, using a stainless steel which contained 17.24% Cr, 0.18% Ni, 0.08% carbon.

The plan was to provide in quintuplicate a series of test panels covering a considerable variation in the areas within the crevices formed by the overlapping stainless steel surfaces as compared with the areas of metal freely exposed outside the crevices. In order to insure that all the crevices would be alike, the separation of the plates that formed the crevices was held constant at .001-inch by machining lands on one of each pair of plates that were assembled to form a specimen. Likewise, in order to confine the action to surfaces of known area and proximity, all other surfaces of the specimens were coated with a baked phenolic varnish applied in two layers to a thickness of about .002-inch and baked for one hour at 350 degrees F.

The specimens so prepared were exposed to the corrosive action of sea water at the International Nickel Company's marine test stations at Kure Beach and Harbor Island, N. C. The first exposure was for 14 days at Kure Beach, and then the specimens were moved to the new station at Harbor Island where the exposure was continued for another 73 days (June to September) for a total of 87 days.

At Harbor Island, the specimens were exposed in a wooden trough through which clean sea water of full salinity flowed at a rate of about two feet per second (150 gallons per minute). The temperature varied between about 75° and 85° F during the exposure at Harbor Island.

In order to prevent the adherence of marine organisms which would have developed crevices under their bases in addition to the crevices that we had provided, the freely exposed surfaces of the specimens were scrubbed regularly (at least once a week) with a bristle brush to remove the organisms before they could introduce another corrosive effect.

At the end of the exposure described, the specimens were disassembled for weight loss and depth of corrosion measurements. At that time, it was discovered that the phenolic coating had deteriorated on some of the specimens — especially those with the largest freely exposed areas — and had, in effect, created additional crevices beyond those formed by the overlapping stainless steel surfaces. The orderly pattern of area relationships which had been sought was upset a little by this development but, nevertheless, the results of the test served very well to confirm and illustrate the principles being investigated.

These results are shown by the graph in Figure 2 in which the total weight losses of the pairs of specimens are plotted against the area of freely exposed metal outside the crevice in each case. Each point on the graph represents the arithmetical average of

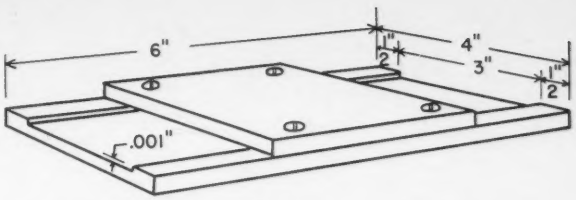

Figure 1—Sketch of design of crevice corrosion specimens.

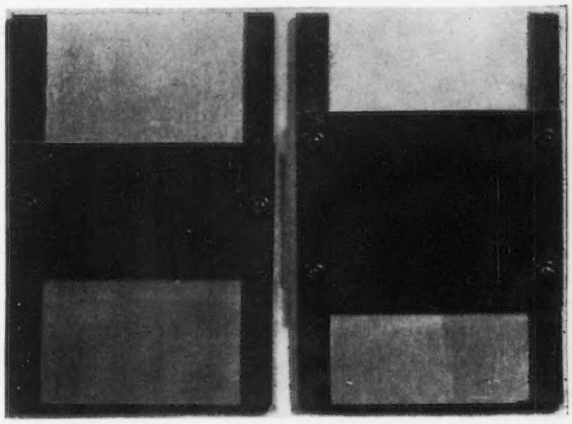

Figure 1A—Crevice corrosion specimens before exposure.

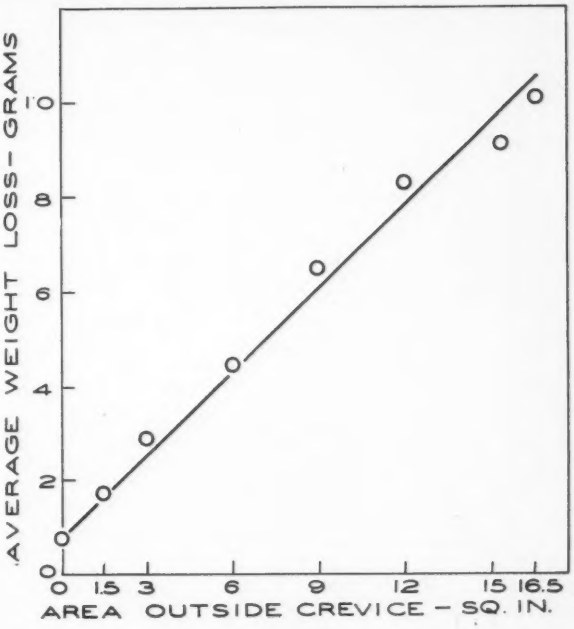

Figure 2—Average weight loss of specimens versus area of specimen outside the crevice.

five duplicate specimens. There was excellent agreement among the duplicate specimens as indicated by a coefficient of variation which ranged from 4.4 percent to 11.0 percent in the several combinations.

Similarly, in Figure 3 the average maximum depth of attack is plotted in the same way.

The appearance of a typical set of specimens after exposure is shown in Figure 4.

The data secured confirmed the expectation that

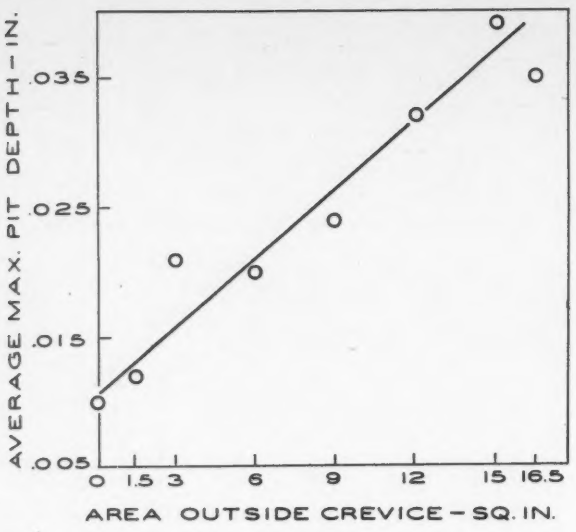

Figure 3—Average maximum pit depth within the crevice versus area of specimen outside the crevice.

the extent of attack within a crevice would be proportional to the area of the freely exposed metal outside. This means, of course:

1) that the greatest danger lies in cases where a crevice is associated with a large area of freely exposed metal and
2) that where the area of metal outside a crevice approaches zero the extent of corrosion within the crevice will also approach zero and will be determined only by the access of the corrosive medium and oxygen to surfaces within the crevice.

Perhaps it should be noted here that crevice corrosion may also involve the mechanism of a metal ion concentration cell (as encountered sometimes with high copper alloys in environments in which copper corrosion products are readily soluble). If this should be the case, then the cathode would be within the crevice and the anode outside. The accelerated attack would occur outside the crevice and would be expected to be reduced in intensity rather than increased when the area of freely exposed metal is increased.

Because of the relatively high resistance of the thin layer of electrolyte within a crevice which would tend to restrict the active cathodic area to the area near the mouth of the crevice, it would not be expected that an increase of the area of the *cathodic* metal *within* a crevice would have anywhere near as strong an effect in accelerating metal ion concentration cell corrosion of the *anodic metal outside* the crevice—as was observed in the present case when the *cathodic* area *outside* the crevice was enlarged.

The effect of the high resistance of the electrolyte would also tend to confine corrosion within a crevice due to differential aeration effects to the areas near the mouth of the crevice. To the extent that this would bring about an unfavorable cathode-to-anode area relationship it would aggravate the effect—but compensating for this would be the natural effect of the high resistance of the electrolyte in reducing the galvanic currents that could flow. At the same time, the enlargement of the crevice by corrosion, with a resulting relatively small increase in area under attack as compared with the reduction of the resistance of the electrolyte, would lead one to expect that, with an unfavorable area relationship crevice corrosion once started would progress at an increasing rather than a diminishing rate until the polarization of the cathode surfaces would assume major control.

Additional tests to check these speculations would be interesting.

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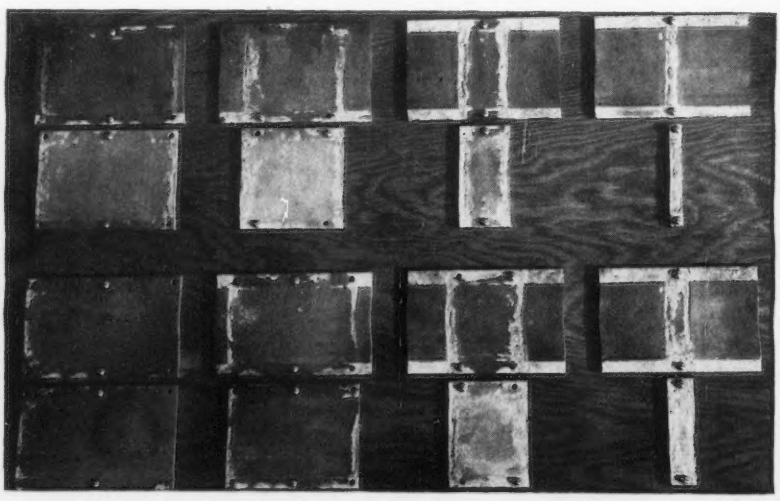

Figure 4—Typical crevice corrosion specimens after exposure.

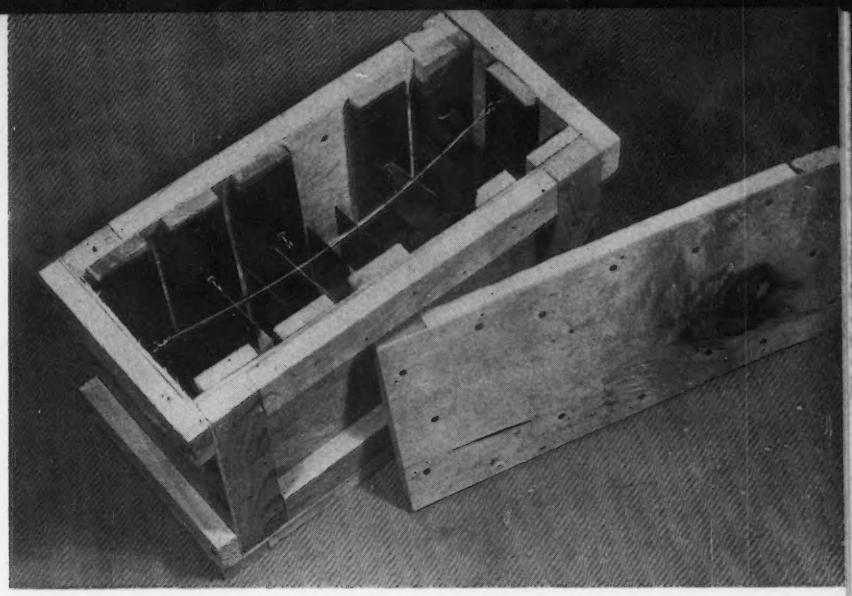

Figure 1—Plywood box and specimens.

Effect of Packaging on Corrosion Of Zinc Plated Equipment*

By K. G. COMPTON, S. M. ARNOLD and A. MENDIZZA

MANY FERROUS parts of telephone apparatus and equipment for use within the continental United States are finished with an electroplated coating of zinc, 0.0002-inch thick. As a rule this finish has given adequate protection against the corrosive attacks of normal indoor central office atmospheres. Moreover in the past, no particular difficulties have been experienced with apparatus stored under normal conditions.

In the spring of 1947 an unexpected strike by installers necessitated the storing of large quantities of telephone apparatus and equipment for periods considerably in excess of that which was the custom. The suddenness of this emergency compelled the employment of additional storage facilities, which in some cases were admittedly poor, but were the best available at that time. When work was resumed in the field, it was discovered that the zinc finish on an appreciable quantity of equipment was very severely corroded; some equipment requiring costly refinishing, other replacement. Some of the most severely corroded equipment had been stored for periods up to 11 weeks under severe environmental conditions in the southern part of the United States. While the poor condition of the equipment was attributed to the fact it had been stored for considerable time during an exceptionally humid and hot part of the year, and in some instances under very poor storage conditions, it was felt that other factors, principally the type of packaging, were also contributory. When corrosion ot the stored equipment was first observed, it was noted that parts which had been packed in paper cartons were in better condition than were those in plywood boxes. Hence, the investigation discussed in the present article.

In view of the rather large extent of the damage and the possibility this contingency might reoccur, it was deemed necessary to ascertain the cause or causes for this widespread corrosion and the reasons for the differences noted in the degree of corrosion, particularly of zinc plated parts. A preliminary investigation was therefore made. These preliminary tests had a two-fold objective: First, to develop in the laboratory corrosion of the type experienced in the field; second, to determine whether the type of packing material affected the degree of corrosion, and if so, what physical or chemical characteristics were responsible.

The test which was designed to simulate, and in some degree, accelerate the corrosion obtained in storage under circumstances in which the relative

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Abstract

Packaging can sometimes be conducive to unexpected, and at times very unpleasant experiences, often resulting in loss of valuable equipment and time. Experience of a large company manufacturing electrical equipment is illustrative of problems that arise, and which eventually led to a broad investigation of packaging and its effect on the corrosion of zinc plated equipment and apparatus.

An unexpected strike in the field necessitated storing large quantities of equipment for periods considerably in excess of that which was ordinarily the custom. The suddenness of this emergency compelled employment of storage facilities over and above those normally needed which in some cases were admittedly poor, but were the best available at the time. When work was resumed in the field it was discovered that appreciable quantities of equipment were very severely corroded, some requiring costly refinishing, others actual replacement. While the condition of the equipment was attributed to storage for considerable lengths of time during an exceptionally humid and hot time of the year, and in some instances under very poor storage conditions, it was felt that other factors, principally the type of packaging, were also contributory. When the corrosion of the stored equipment was first observed, it was noted that parts which had been packed in paper cartons were in better condition than were those in plywood boxes.

In view of the extensive damage and the possibility this contingency might reoccur it was deemed necessary to ascertain the cause or causes for this wide-spread corrosion and the reasons for differences in the degree of corrosion. A preliminary investigation was made in an attempt to duplicate in the laboratory the type and extent of corrosion encountered in the field. Encouraging results of these first tests led to an extension of the work. The purpose of the second and more comprehensive study was to determine what effect, if any, various packaging materials and methods of packing had on the rate of corrosion, what physical and/or chemical factors were controlling, and what remedial measures were indicated in order to prevent, or minimize a repetition of this trouble. This investigation attempts to answer these questions, and indicates the desirability of further work in order to clarify some of the questions not yet completely and satisfactorily answered.

humidity and temperature were high, was carried out in a controlled humidity chamber. The test cycle consisted of two periods daily. One of approximately six hours duration during which time temperature and relative humidity were maintained at respectively 80 degrees F and 90 per cent RH, and an 18-hour period during which time the temperature was kept at 100 degrees F while the humidity remained at 90 per cent. The changes in temperature were fairly rapid so as to promote condensation on the metallic parts of the equipment. These, because of their high heat capacity, lag behind in a period of rising temperature.

The duration of the test was 29 days. During this time the equipment and specimens under test were inspected several times. The decision to terminate the test after 29 days was prompted by the condition of certain units. These in appearance closely resembled the equipment most severely corroded during the extended storage in the field.

Central office equipment obtained from two different manufacturing locations were employed in this investigation. Units from each location were packed in several standard types of containers including corrugated paper, fiber board, plywood and ventilated plywood boxes. Ventilation was provided by several holes at the top and bottom sides of the container.

All these boxes, with the exception of the ventilated containers, are in general use for packing telephone equipment. The ventilated boxes were included to determine the effect of air circulation within the package under the conditions of the test. The fiber board boxes contained a considerable amount of wood in the form of support for the packed units. The plies used in the plywood boxes are made from hardwoods, such as white ash, rock elm, birch, hard maple, oak, etc. The glue used in making these plywoods is vegetable in origin, consisting of starches and proteins. The paper cartons are standard quality corrugated paper consisting of kraft paper facings and straw pulp corrugations.

In addition to these specimens, one unpacked unit from each manufacturing location was also placed in the test chamber. Also a number of laboratory prepared test panels were placed in a plywood box along with one of the test units. Included were cold rolled steel panels finished as follows:

a. Electroplated bright zinc, 0.0002-inch thick (standard finish for central office).
b. Same as "a" except that the panels were aged at 215° F for two days.
c. Same as "a" plus a propriatary chromate treatment.
d. Same as "a" plus a different proprietary chromate treatment.
e. Unfinished cold rolled steel.

The chromate treatments used in the tests produce films that are somewhat similar in nature to those produced by the sodium dichromate-sulfuric acid treatment known as the "Cronak" process, excepting that the coatings have less color and irridescence. Preliminary tests had indicated they would substantially increase the resistance of a zinc finish to white corrosion and finger printing.

The finished panels were finger printed on one side in order to observe the reaction of this type of contamination. To provide a uniformly clean surface the unfinished steel panels were cleaned by polishing with magnesium oxide powder, solvent degreased and alcohol rinsed. These last were not finger printed.

An inspection of the samples after the 29-day test showed that in general the equipment packed in corrugated paper boxes had corroded less than that in the fiber board boxes and this in turn was attacked to a lesser degree than units in the plywood containers. This observation confirmed the reports from the field that equipment in paper cartons suffered less during the prolonged storage than that packed in plywood. It was noted that although the overall degree of corrosion of the packed units was similar to that experienced in the field, certain parts suffered less corrosion while others were in worse condition. This difference in behavior is probably due in a large measure to the extreme difficulty in artificially reproducing actual field conditions. It was also noted that the corrosive attack on packed equipment lagged behind the unpacked units during the earlier part of the test but that it apparently gathered momentum as the test progressed and ultimately equalled or even surpassed it. This was particularly true for the plywood and fiber board

packages, indicating that the conditions within the boxes are in some definite manner related to the type of materials used in their construction.

The results obtained with the ventilated plywood boxes showed that no advantage is gained thereby. It was noted that units in the ventilated boxes corroded slightly more than their counterparts in the unventilated boxes during the early part of the test. This tendency was obliterated as the test progressed.

The laboratory prepared samples showed the same trend as the manufactured equipment, except that the effect of different containers was much more outstanding. This is probably due to the better controlled finish and greater uniformity of base metal used for the laboratory samples.

Several chemical analyses of the products of corrosion of zinc plate which had been exposed in wooden boxes under similar circumstances have been made in the past, and the presence of traces of the salts of the lower fatty acids have been reported. In some cases acetates have been identified. It is recognized that some organic contaminants will accelerate the corrosion of zinc in the presence of a film of moisture. In order to determine whether acetates do emanate from the plywood used in the storage tests experiments were performed in which it was attempted to collect volatile components. In one of these, shredded plywood was stored directly above water at room temperature in a sealed glass container for several weeks. Air saturated with water was periodically drawn through the test chamber and all volatile components frozen in a trap surrounded by liquid air. The chamber was maintained at a temperature of 90 degrees F. Tests for acetates in the condensate were made with uranyl nitrate. This reagent reacts with acetates to yield a well defined crystalline compound of sodium uranyl acetate which may be identified under a microscope. These tests were negative up to a period of three weeks. In another experiment shredded plywood samples were kept dry and were evacuated continually during the day for a period of about one week. Volatile compounds were likewise collected by freezing. Tests for acetates in this condensate were also negative. In order to further increase the sensitivity of the tests, the condensates were concentrated in a microstill. Negative results were obtained in all cases. Tests for acidity showed that acid, if present, was in concentrations of less than two parts per million. No acetates were found in any of the corrosion products removed from the equipment under test.

Additional Packaging Tests

In view of the satisfactory performance of the chromate treatments on laboratory prepared panels, it was decided, at the completion of these preliminary tests, to evaluate the effectiveness of similar treatments on shop finished products. A number of pieces of equipment were therefore finished with different types of chromate treatments at one of the manufacturing locations and submitted to the cycling tests previously described. The duration of this test was only 21 days, eight days less than the previous test. The earlier termination was prompted by the seemingly more severe rate of corrosion of the untreated zinc finish in the plywood box.

From inspection of these latter test results, it was again evident that the equipment packed in plywood corroded to a greater extent than that packed in cardboard, paralleling closely the results obtained in the earlier packing tests. None of the treatments were effective in completely preventing corrosion of finger prints on the equipment packed in plywood, although some treatments appeared to be better than others. Practically all treatments were equally effective in reducing white corrosion and finger printing on the units packed in cardboard.

Tests for acetates in the corrosion products of the untreated zinc plated units packed in plywood were made soon after the completion of the tests and again about two weeks later, using the method previously described. They were positive in both instances. This is in direct contradiction to the negative results obtained in the first tests. This anomaly again serves to emphasize the variability in test results that may be expected in investigations of this type, particularly when dealing with packing materials such as plywood whose history is an unknown factor and whose source may differ greatly from test to test.

Similar phenomena in which corrosion of equipment variously packed occurred in varying degrees has been observed by other investigators. C. G. Lavers and co-workers[1] found that steel samples packed in a carton or with a kraft paper overwrap corroded less severely than when coated with a rust preservative and intimately packed after a prolonged exposure to cycling humidity and temperature tests. They attribued the superiority of the carton over-wrap to the sorption action of the carton. This assumption was based on the fact that the amount of water vapor that paper can absorb increases rapidly at relative humidities above 75 per cent, and that for a given relative humidity the equilibrium moisture content of paper increases slightly as the temperature decreases.[2] R. C. Rietz and L. O. Anderson[3] of Forest Products Laboratories also observed the sorption action of paper in minimizing corrosion of packed equipment.

Since by the use of corrugated paper there appeared to be a substantial gain from the standpoint of corrosion, a cursory experiment was performed in which one set of test panels was placed in a plywood box lined with a light-weight corrugated paper. These boxes were submitted to the cycling test described in the preceding pages for a period of four weeks. The results obtained from this test clearly indicate that the panels exposed in the corrugated paper lined plywood box had corroded to a considerably smaller degree than those in the unlined plywood box. The encouraging results obtained from these experiments led to a decision to extend the investigation to include other packaging materials and various types of linings for possible use with the plywood containers.

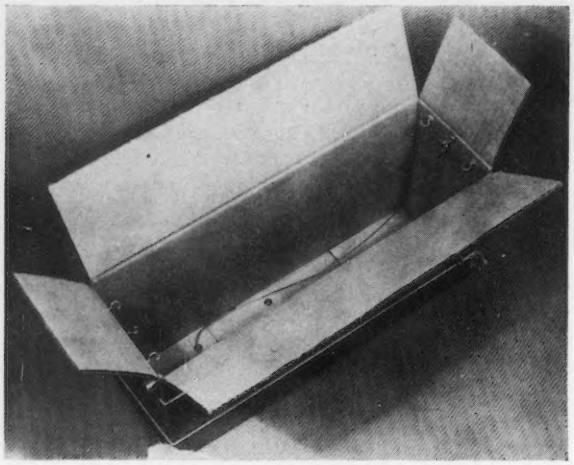

Figure 2—Corrugated carton.

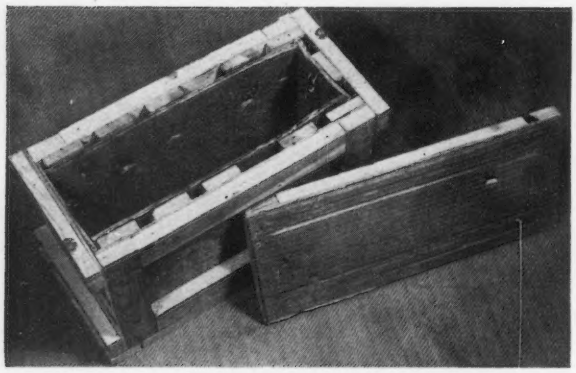

Figure 3—Corrugated paper lining.

TABLE I—Containers Used in Packaging Study

Container	Treatment of Lining	Remarks
1. Plywood Box	No lining	Type now standard for certain types of telephone equipment.
2. Plywood Box	Interior surfaces paraffined	
3. Plywood Box	Corrugated paper enclosure	
4. Plywood Box	Corrugated paper enclosure, ½ only of the wood surface covered.	To simulate incomplete or faulty coverage.
5. Plywood Box	Wax paper enclosure	
6. Plywood Box	Kraft wrapping paper enclosure.	
7. Plywood Box	Aluminum foil enclosure	
8. Plywood Box	100 gram Activated charcoal	Enclosed in muslin bag
9. Plywood Box	500 gram Activated charcoal	Enclosed in muslin bag
10. Plywood Box	100 gram Shredded Corrugated paper	Enclosed in muslin bag
111 Plywood Box	Fabric enclosure	Cotton sheeting
12. Plywood Box	Creped Kraft insulating paper	
13. Plywood Box	Vistanex coated creped Kraft insulating paper	Polyisobutylene
14. Plywood Box	Glass wool lining	
15. Plywood Box	Corrugated paper outside-wrap	
16. Plywood Box	Kimpack Wadding Enclosure	A soft, absorptive cellulosic wadding
17. Plywood Box	Coppa wadding enclosure	A standard inexpensive packing for fragile shipments
18. Plywood Box	Hair Felt Enclosure	Formerly used in limited amounts, but more expensive than Coppa wadding
19. Corrugated Carton	No lining	Standard type container
20. Corrugated Carton	Interior surfaces paraffined	
21. Fiberboard "A" Box	No lining	Standard type container
22. Fiberboard "B" Box	No lining	Type contemplated for use for telephone equipment
23. Craveneer	No lining	Composite of wood faced with paper.

Extended Packaging Tests

The materials selected for these additional tests included a number of conventional packing materials. Also some, which, while not practicable for packing, it was hoped might shed some light on the mechanism of the corrosion reaction and possibly point to the direction of a better packaging medium.

Materials Used

For the major part of this study, plywood boxes and corrugated cartons, approximately 17 in. x 8 in. x 11 in. overall were used. This size is standard for certain types of telephone equipment. In addition, a few containers of two types of fiberboard and one made of a material consisting of a composite of wood faced with paper, were included. This material is called "Craveneer." Plywood, cardboard and one fiberboard are used currently for packing telephone products. Table I lists the containers and the lining materials used in this investigation. Excepting as noted, all of the interior surfaces of the plywood were covered by the lining although no attempt was made to seal overlapping or butting edges. Figures 1 to 3 illustrate some of the containers used in this test.

The activated charcoal, containers Nos. 8 and 9, was included to determine whether an absorbent for water vapor and organic vapors had any direct influence on the rate of corrosion. Inasmuch as the earlier tests had indicated the benefits obtainable from lining the plywood with corrugated paper, the question arose as to whether merely having paper present might not be sufficient. The shredded corrugated paper, container No. 10, was included for this purpose. Container No. 14, the glass wool lining, was added in order to ascertain whether differences in heat conductivity of the packing materials bore any relation to the degree of corrosion. The corrugated paper over-wrap, container No. 15, was to answer the question as to whether the paper lining of the plywood box merely acted as an additional wall thickness between the outside environment and the contents of the box. It was reasoned that if this were so the same beneficial effect must be obtained regardless of whether the corrugated paper was used as an enclosure or as an overwrap. The various other types of linings were included to determine whether the indicated advantages secured with the corrugated paper could be extended through the use of other materials. Containers Nos. 21, 22 and 23, the two fiberboards and the "Craveneer" box, were included with the thought of obtaining additional information toward the solution of this problem.

In addition to the containers listed above, several other plywood and cardboard boxes were used for studying temperature and humidity changes as well as the effects of mass of specimen, while others were included to act as monitors. Specimens in the latter boxes were examined during the course of the exposure period in order to follow the progress of the test.

Test Specimens

The samples used in this part of the investigation consisted of cold rolled steel panels, 2 in. x 3 in. x 1/32 in. The following finishes were applied:

a. Electroplated bright zinc, 0.0002 in. thick.
b. Electroplated bright zinc plus a commercial chromate-type treatment.
c. Electroplated bright zinc plus the "Cronak" treatment.
d. Unfinished steel.

Duplicate samples were arranged in the test boxes listed in Table I as shown in Figure 1. Inasmuch as fingerprinted areas, such as produced by excessive handling, are known to be subject to highly localized corrosion, all test panels were fingerprinted on one side. While it is recognized that it is almost impossible to apply reproducible fingerprints, it was felt that some valuable information might be obtained from this test.

To determine the effect of mass of sample on corrosion, duplicate sets of steel panels, in thicknesses of 1/64-in., ⅛-in. and ¼-in., were zinc plated and placed in a cardboard and a plywood box. Temperature changes outside as well as within the boxes and actual specimen temperatures as affected by mass of sample were followed by means of thermocouples. The boxes were exposed to a cycling humidity and temperature test, analogous to the one previously described, for four weeks.

Observations at Termination of Test

When the containers were opened, very marked differences in the amount of corrosion were at once apparent. It was found that the containers could be grouped into three main categories according to the degree of corrosion of the included specimens.

As the specimens of chief interest were those which had been zinc plated and those which had been zinc plated and treated with a chromate finish, the rating given the containers and shown in Table II was based on the condition of these specimens. Owing to minor variations, it was not always possible to grade the container definitely relative to each other in a descending scale in all cases. However, there was no question as to marked differences among the members of each of the three groups. Figures 4 to 6 show specimens from some of the containers arranged according to the amount of corrosion.

Discussion

As can be seen from Table II, a lining of corrugated paper within the plywood box was sufficient to minimize in large part the corrosion which otherwise would have occurred. That this improvement was not merely due to the presence

TABLE II—Rating of Containers

Arranged in descending order of merit based on the corrosion found on the included specimens.

	Remarks applying in general to the condition of all the specimens in the particular group
Group 1	
1. Plywood Box—Corrugated paper enclosure 2. Plywood Box—Hair Felt enclosure 3. Corrugated Carton—Interior Paraffined 4. Corrugated Carton	Steel specimens—Considerable finely divided rust. Zinc plate—In good condition. Slight scattered white corrosion, particularly at the finger prints. Chromated—Good condition. Slight indication of finger prints. Cronak—Good condition.
Group 2	
5. Fiberboard "B" 6. Fiberboard "A" 7. Plywood Box—⅛ Corrogated paper enclosure	Similar to Group 1 except that there was increased corrosion of the zinc plate, and increased evidence of finger prints on the chromated specimens.
Group 3	
8. Plywood Box—Coppa Wadding Enclosure 9. Plywood Box—Kimpack Enclosure 10. Plywood Box—Glass Wool Enclosure 11. Plywood Box—Meta Foil Enclosure 12. Plywood Box—Shredded Paper 13. Plywood Box—Activated Charcoal—100 grams	In general, increasing amounts of rust were found on the steel although there were a few exceptions. The rust also appeared coarser in structure. Number 8 (Coppa wadding enclosure) was the first container in which general overall white corrosion or the zinc plated parts was found. Increasing amounts of rust were visible on the zinc plated parts, covering about 50 per cent of the area of those in number 15 (wax paper enclosure) and ranging up to 90-95 per cent of the area of those in the last 3 containers.
14. Plywood Box—Corrugated paper over-wrap 15. Plywood Box—Wax paper Enclosure 16. Craveneer 17. Plywood Box—Activated Charcoal—500 grams 18. Plywood Box—Vistanex Creped Kraft Paper Enclosure 19. Plywood Box—Fabric Enclosure 20. Plywood Box—Kraft Paper Enclosure 21. Plywood Box—Interior Paraffined 22. Plywood Box 23. Plywood Box—Creped Kraft Paper Enclosure (The rating of this last container may be lower than justified. A leak during the first week of the test caused actual wetting of the contents.)	There was a little further change in the chromated specimens, most showing marked corrosion at the finger prints. There was little change in the Cronak treated specimens, all being in good condition apart from slight corrosion at some of the finger prints and this was not consistent.

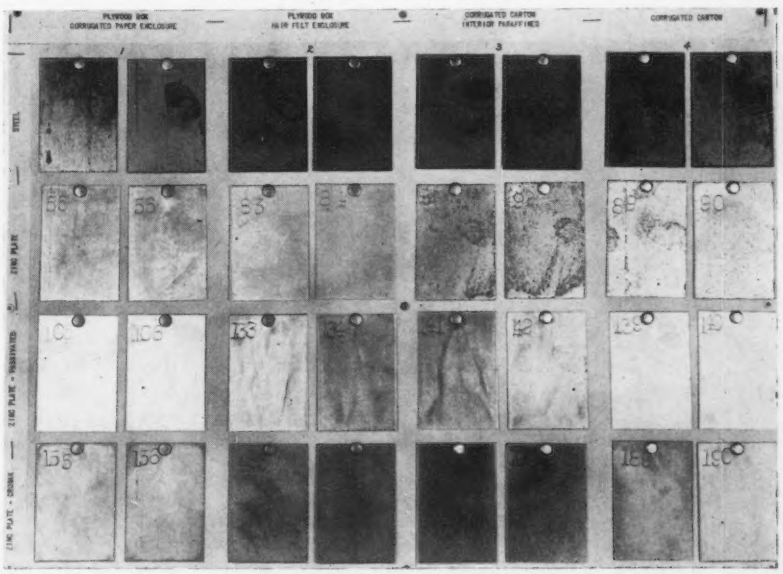

Figure 4—Panels after test.

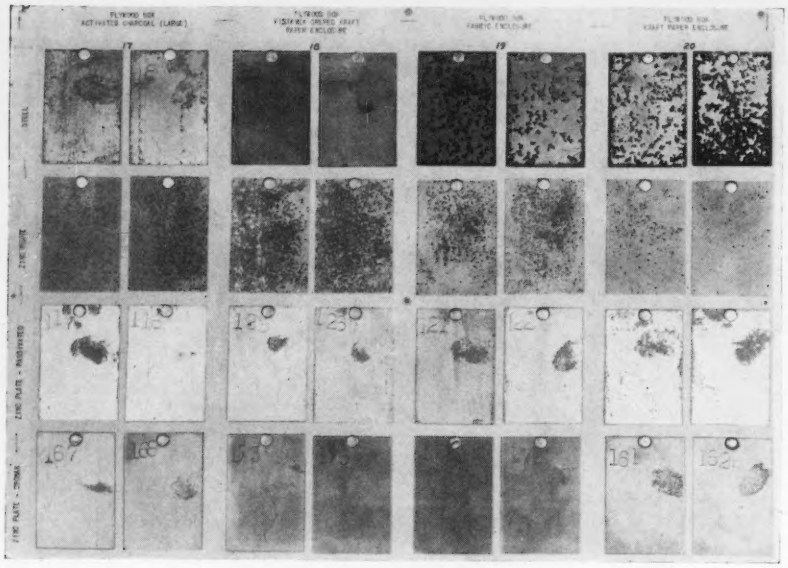

Figure 5—Panels after test.

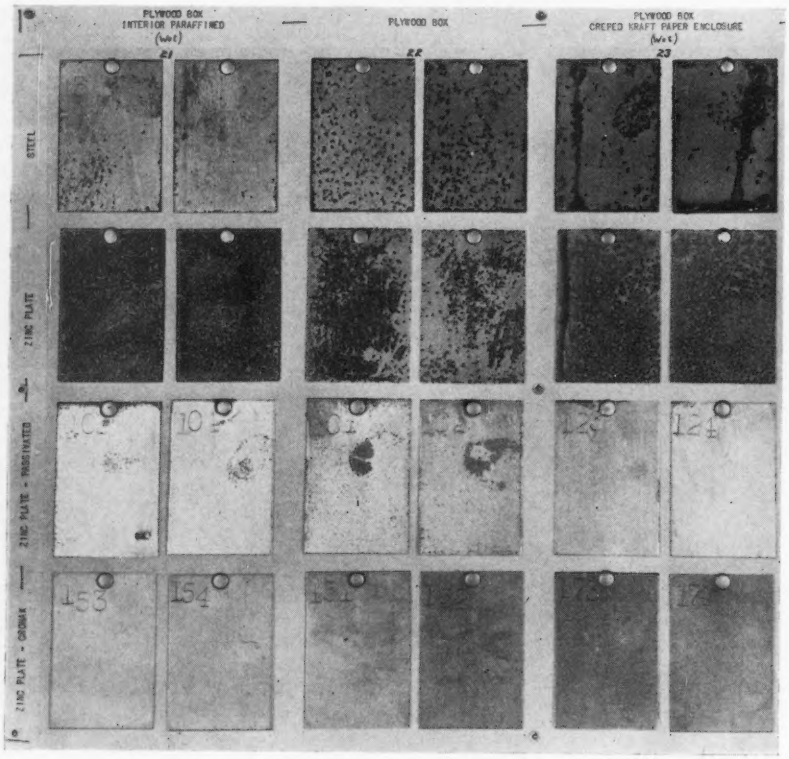

Figure 6—Panels after test.

of a physical barrier alone was shown by the lack of protection afforded by the external wrap of the same material, and also by the fact that a loosely fitted lining of metal foil was not sufficient to prevent corrosive attack. Furthermore, a lining of glass wool which was to act as a thermal barrier but which had little to offer as an absorptive medium, was of little use in preventing corrosion. Linings of other materials varied greatly insofar as affecting the corrosion rate was concerned, but none of them proved to be superior to the corrugated paper. Fiberboard appeared relatively high in the table of container ratings and within its limitation of strength should prove a satisfactory packaging medium. The mere presence of an absorptive material within a plywood container was not sufficient to prevent corrosive attack. Neither shredded corrugated paper nor activated charcoal were effective. Regardless of the type of container, the supplementary finishes were very effective in decreasing the rate of corrosion of zinc plated parts. Even in the containers where the bright zinc was most severely corroded, there was little corrosion of the treated panels. Of the two supplementary finishes that obtained by the "Cronak" process appeared to be slightly superior.

These tests again indicated that condensation of moisture was the principal cause of corrosion inasmuch as attack had occurred in all containers regardless of type of construction or material. However, the possibility that minute quantities of contaminants emanating from the plywood might have contributed to the corrosion cannot be entirely excluded. This is borne out by the fact that even though the relative humidity within the corrugated carton actually was found to be higher than that within the plywood box, in both cases following parallel courses with changing room conditions, nevertheless the corrosion was found to be considerably worse within the plywood container. As pointed out in the earlier part of this paper, proof that volatile contaminants actually contribute to the corrosive attack is difficult and analytical data at present appears to be contradictory.

Effect of Mass of Specimen

Table III and Figure 7 show how the specimens of different metal thickness corroded, both in a corrugated carton and in a plywood box. As had been expected, corrosion was less on the very thin panels and progressively worse as the thickness increased. Here again the beneficial effect of the carton wrapping is plainly evident.

Temperature and Humidity Study

Figure 8 shows that the temperature changes within the corrugated carton followed outside en-

vironmental changes more closely than did those within the plywood box. The time lag was approximately 5 to 7 minutes as compared with 15 to 20 minutes for the latter during a rapid change in room conditions. From this, one would expect differences in the conditions of specimens to exist in the two containers, and this is clearly shown in Figure 9 where the temperature of the ¼-in. thick panel in the plywood lags behind that of an identical panel in the carton by approximately 15 minutes. Figures 10 and 11 show, as would be expected, that panels with a minimum of mass closely follow temperature variations of the environment.

An attempt was made to obtain readings of humidity conditions within the boxes. The data obtained are represented by the curves in Figures 12, 13 and 14. The upper broken line represents the instantaneous values of the relative humidity of the incoming air measured at the duct. For reference purposes a curve showing the temperature of the room throughout the same period is shown along with the humidity curves. Figures 12 and 13 show the conditions prevailing within the containers during the second and third days of the test. Figure 14 was plotted for the final day and indicates that the conditions within the plywood box more closely approach those within the carton as the number of cycles increased, although the humidity within the carton still remained above that in the plywood box. Apart from the indications of higher relative humidity within the carton, the curves also point to humidity changes within the containers which parallel the room temperature cycle. While these data throw some light on the mechanism of the corrosion process it is felt that additional work along these lines is still in order. It is particularly felt that more reliable humidity measurements are required at the actual surfaces of the specimens before more positive conclusion can be drawn.

Conclusions

Laboratory tests on equipment having zinc plated parts have produced corrosion to an extent comparable to that encountered in the field and which is known to be caused by condensation of atmospheric moisture. Furthermore, the greatest cor-

TABLE III—Variation in Corrosion of Zinc Plated Specimens of Different Thicknesses

Thickness of Specimen in inches	CONDITION
Corrugated Carton:	
1/64	Bright except for slight indication of finger prints.
1/8	Slight grey film with scattered pin points of white corrosion product.
1/4	Uniform grey film with scattered pin points of white corrosion product.
Plywood Box:	
1/64	Approximately 5 per cent of the surface still bright, the remainder coated with grey white corrosion product, and some scattered rust.
1/8	Slightly darker grey film of corrosion product with an estimated 5-10 per cent of the surface showing pin point rust.
1/4	Surface covered with dark grey film, with approximately 20-30 per cent of the area covered with small areas of rust.

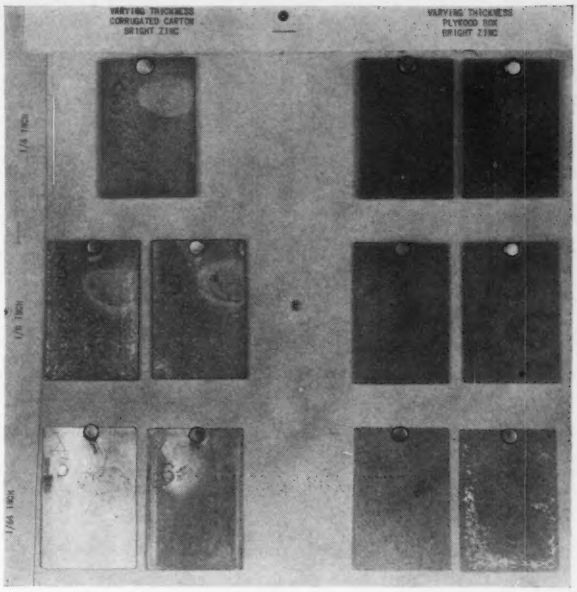

Figure 7—Effect of mass on amount of corrosion.

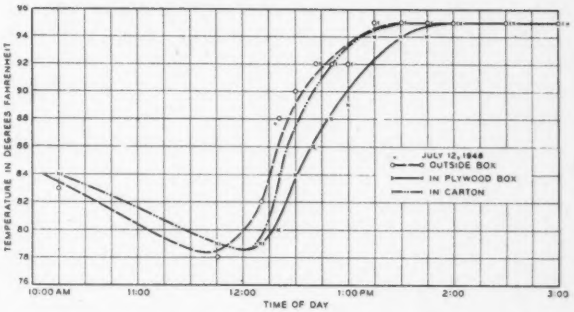

Figure 8—Temperature variation inside and outside containers.

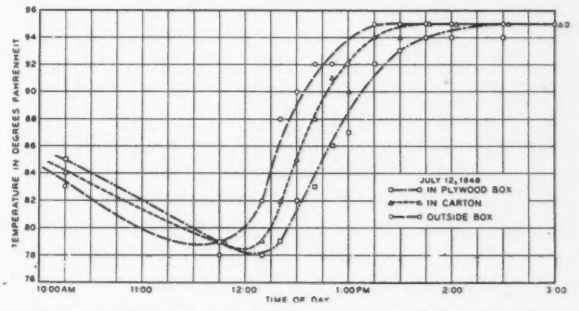

Figure 9—Temperature variation—one-quarter inch specimens.

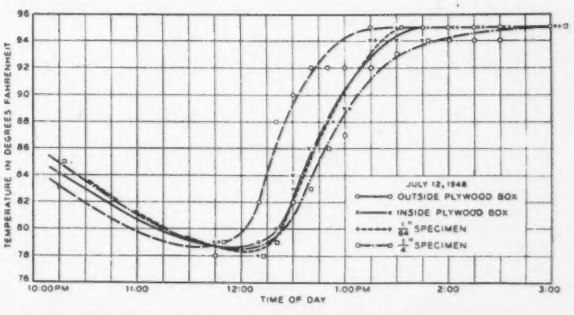

Figure 10—Temperature variation with metal thickness—Plywood.

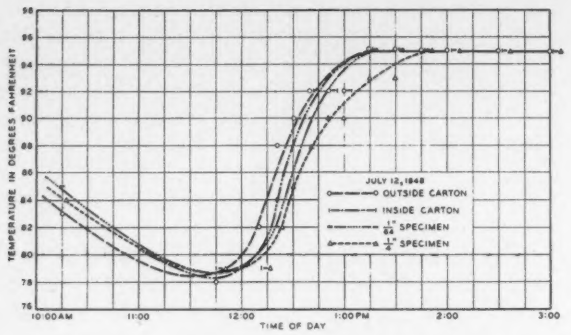

Figure 11—Temperature variations with metal thickness—Cartons.

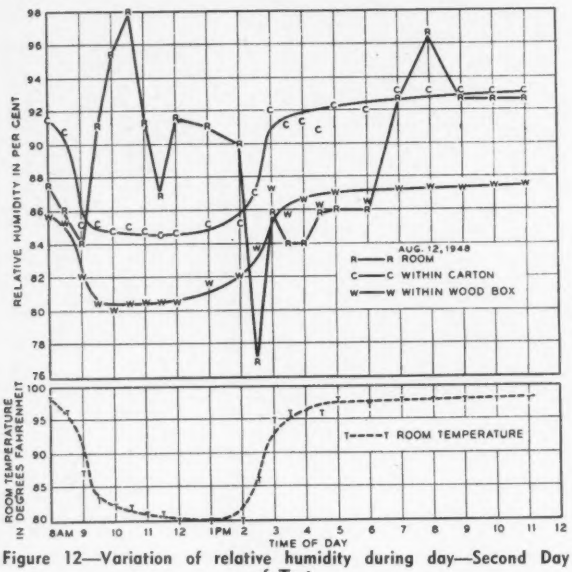

Figure 12—Variation of relative humidity during day—Second Day of Test.

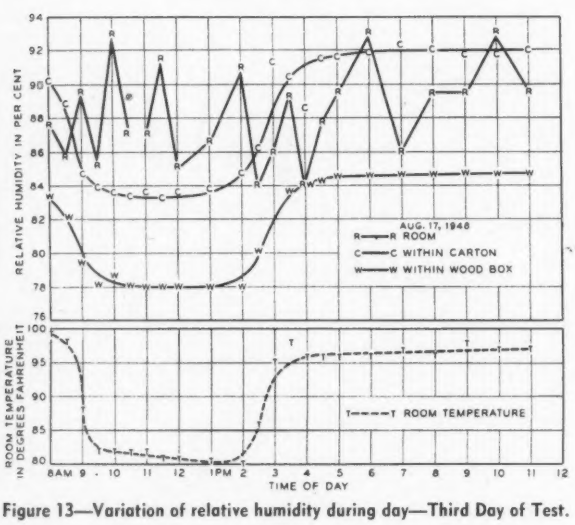

Figure 13—Variation of relative humidity during day—Third Day of Test.

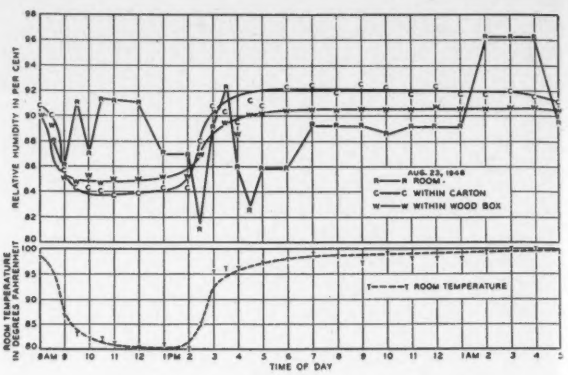

Figure 14—Variation of relative humidity during day—Final Day of Test.

rosion occurred when the zinc plated parts were packed in plywood boxes, somewhat less in fiberboard and least when packed in corrugated paper boxes. It is believed that corrosion was due to condensation of moisture and that the differences in the extent of corrosion were primarily due to inherent physical properties of the packing materials, of which moisture absorption rates were probably of first importance. It is possible that heat transfer rates also played a part. Under the conditions of the test organic contaminants such as traces of acetic acid emanating from plywood may have had an accelerating effect on the corrosion rate. It is noteworthy, however, that tests for acetates in the corrosion products were negative in one test and positive in a later one. The investigation has also shown that a supplementary chromate treatment of zinc plated parts provides a marked increase in the resistance to corrosion.

As a result of this study we feel assured that zinc plated and chromate treated parts, packed in corrugated paper boxes or in plywood boxes lined with corrugated paper, would be adequately protected against storage conditions equivalent in severity to those which prompted this investigation.

The authors express their thanks and appreciation to A. W. Rogers, Head of the Materials and Component Group at the Squier Laboratory, U. S. Signal Corps, and his associates A. J. Brickler, T. M. Child and C. P. Lascaro for their kind cooperation and assistance and for the use of a test chamber to carry out a part of this work.

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Historic Church's Copper Roof Good After 213 Years *

By A. W. TRACY*

CHRIST CHURCH at Market and Second Street, Philadelphia, Pennsylvania, was built between the years 1727 and 1745 and has become a national shrine because of its historic association. George Washington, Benjamin Franklin, Robert Morris, Betsy Ross and many other persons who took active parts in the founding of this nation were members of or attended this church. The roofs over the nave and the aisles in Christ Church were sheathed with standing-seam copper roofs around 1737. The copper was probably imported from England because no mills for the rolling of copper were known to be in existence in this country at that date.

Figure 1 is a general view of the church showing parts of the copper roofs. The balustrades on the roofs over the aisles of the church were originally made of wood but these required occasional replacing due to rotting from fungus action. A number of years ago the balustrades were fabricated in copper. The balustrades are coated with white paint for architectural unity and there has been no difficulty in maintaining paint on this metal surface.

In 1950, after approximately 213 years of service, it became necessary to make repairs to the roof over the nave where fastenings had loosened, allowing several copper sheets to be whipped over and damaged. Careful examination showed that the roofs over the aisles were in perfect condition but a number of copper sheets on the main roof were loose, in addition to those damaged by a windstorm. Some of the wrought iron nails, although protected from the weather, had corroded through at the roof line, probably due to action of condensed moisture. In making repairs, seams at loose areas were opened up, new fastenings attached to the roof boards, and the seams reclosed. The success of this operation depended not only on the good ductility of the copper but also bespeaks the special handling by the expert roofers making the repairs. Where copper sheets had been damaged by wind action, they were replaced by new copper sheets 30 in. wide by 60 in. long by 0.021 in. thick (16 ounces per square foot), which was the size of the original sheets. Twenty new sheets were used for making these repairs.

Twenty years ago, when it was noted that some of the copper sheets on the roof over the nave were loose, these had been fastened by driving screws through the sheets along the center line and covering the screw heads with a small piece of copper soldered to the roofing sheet, as shown in Figure 2. Fastening the sheets in this fashion prevented movement during expansion and contraction on some sheets and cross-shaped fatigue cracks formed as seen in the figure. The necessity of fastening metal sheathing so that the metal can expand and contract relatively freely is clearly emphasized by this example.

The copper cleats and the 3-inch wrought iron nails, originally used to fasten the copper pans to the roof boards, are clearly visible at the seam between

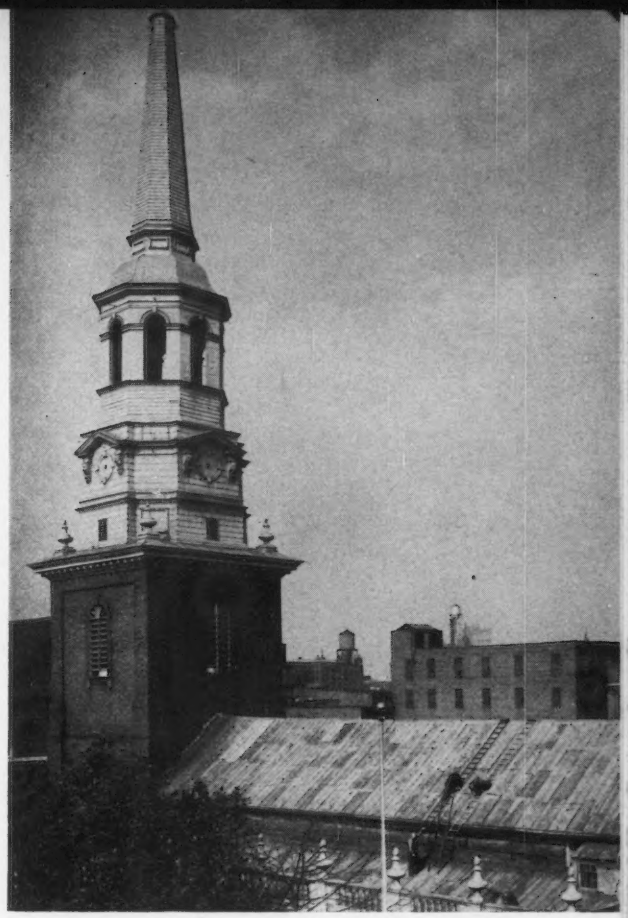

Figure 1—General view of copper roofs on Christ Church, Philadelphia, Pa.

Abstract

An examination of English-made copper sheets taken from the roof of Christ Church, Philadelphia, Pa. after 213 years' exposure shows a weathering loss of 0.007-inch at thinnest areas, equivalent to a corrosion rate of 0.000033-inch per year. It is believed the essentially rural character of the atmosphere during early exposure of these sheets has contributed to their life. Recent corrosion tests on copper sheets in an industrial atmosphere show somewhat higher rates. Rockwell hardness of 15T 61 to 63 indicated the sheets on the church had been finished with a slight temper. Screws driven through the center of some sheets twenty years ago restricted expansion and contraction and caused fatigue cracks. Some of the 3-inch wrought iron nails originally used to fasten the copper pans to the roof boards had corroded through at the roof line, possibly as a result of condensation.

* Submitted for publication June 14, 1951.

* Assistant Metallurgist, Corrosion Research Laboratory, The American Brass Company, Waterbury, Conn.

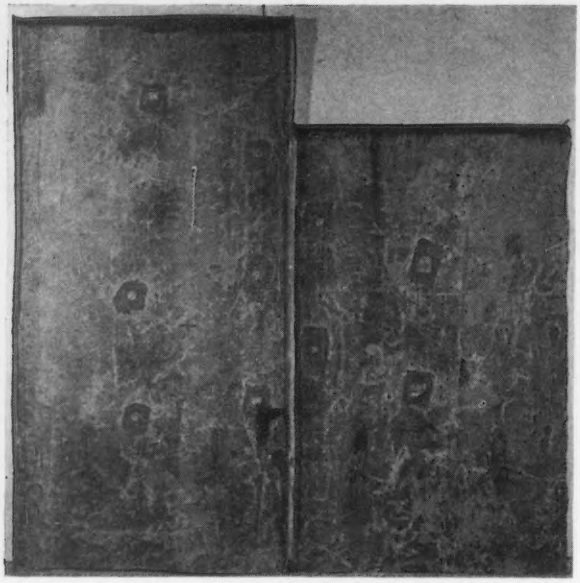

Figure 2—Weather-side of copper sheets removed from roof after about 213 years.

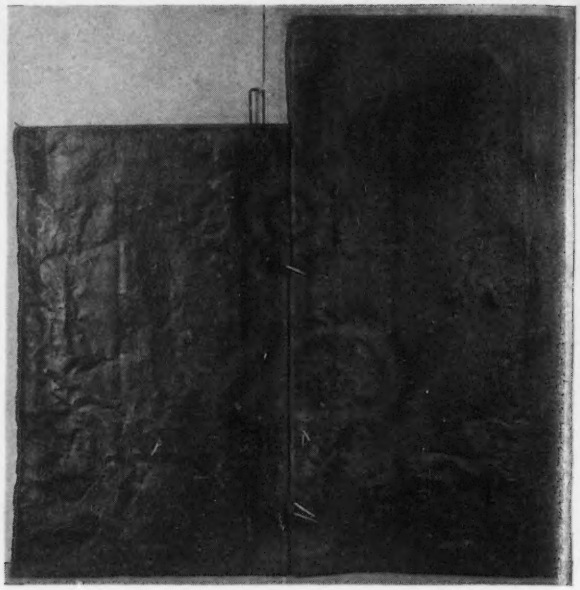

Figure 3—Underside of copper roofing sheets showing copper cleat fasteners. Screws in center line of sheet probably caused fatigue cracks.

two sheets as seen in Figure 3, a view of the underside of two adjacent sheets. The screws driven through the center of the sheets are also to be seen.

Wire snow-guards were soldered to the roof over the nave of the church about 20 years ago and at the same time hanging gutters were installed. Prior to that time, snow and rain water had been allowed to drop from the main roof onto the copper roofs over the aisles. There was no indication that either snow or rain had harmed the lower roofs.

The copper on all the roofs had taken on a green patina on most of the surface but in some areas the copper was black. A micro-chemical analysis of the corrosion products showed the following constituents:

Insoluble Constituents

Basic copper sulfate—very large amount, principal constituent
Basic copper chloride—none
Cupric oxide—very large amount, accounts for most of the black areas found in patina
Cuprous oxide—small amount
Cuprous sulfide—small amount
Ferric oxide—very large amount
Silica—very large amount, probably from decomposition of dust particles
Soot and oil—small amount

Water Soluble Constituents

Sulfates—very large amount
Chlorides—large amount
Ammonia—relatively large amount
Calcium salt—large amount
Copper salt—large amount

The analysis of the patina agrees with other[1] analyses made on copper exposed to urban atmospheres for a number of years in that the chief constituent is basic copper sulfate.

Chemical analysis of the British-made copper from Christ Church indicated it to be a Fire-Refined Copper of lower purity than that found on the market today, as follows:

Copper	99.629%
Silver	0.066
Lead	0.029
Iron	0.003
Nickel	0.016
Selenium	0.0012
Tellurium	0.0011
Bismuth	0.025
Arsenic	0.084
Antimony	0.023
Sulfur	0.0152
Oxygen	0.0828

The copper had a Rockwell hardness of 15T 61 to 63, indicating that the copper had been finished with a slight temper.

Micrometer measurements at seams where the copper would be protected from weathering showed that the metal was originally 0.021-inch thick, equivalent to 16 ounces per square foot. The thinnest areas found on the removed copper sheets were 0.014-inch, making a total loss in thickness of 0.007-inch in 213 years. This is equivalent to a corrosion rate of 0.000033-inch per year. It is interesting to compare this corrosion rate with those obtained from recent tests in industrial atmospheres at other locations. Exposure tests at Waterbury, Connecticut, an industrial atmosphere, and at Winchester, Connecticut, a rural atmosphere, over a period of 10 years,[2] gave the following corrosion rates based on weight losses:

	Industrial	Rural
	Inch Per Year	
Tough-Pitch Electrolytic Copper	0.000038	0.000020
Arsenical Lake Copper	0.000048	0.000015
Fire-Refined Copper	0.000041	0.000020

Other tests[3] gave the following results in a 10-year

test on Tough-Pitch Electrolytic Copper, based on weight losses:

	Inch Per Year
Altoona, Pennsylvania (industrial atmosphere)	0.000046
New York City (industrial atmosphere)	0.000047
State College (rural atmosphere)	0.000023

It is quite probable that the atmosphere in Philadelphia was somewhat rural in character; that is, relatively unpolluted during the initial service of this roof. This could account for the slightly lower corrosion rate of copper on Christ Church in Philadelphia compared to the corrosion rates of copper recently tested in industrial atmospheres.

It is believed that the copper roof on historic Christ Church will give many more years of excellent service and continue to serve as an example of the lasting qualities of copper in corrosive urban atmospheres.

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First Interim Report

Performance of a Comprehensive Group Of Coatings on Steel*

Immersion and Atmospheric Exposures 1949—

By H. W. MUNDT and L. J. THOMPSON**

Summary and Conclusions

Summary. This report and its appendix describe the preparation and exposure of and present the results of laboratory and short-term field exposure performance tests for a comprehensive group of 159 corrosion and fouling retardant or preventive organic coating materials. These materials were used either separately or in combination to constitute a total of 139 protective systems which were applied to steel panel specimens and exposed to seven different local tropical environments which include mean-tide and continuous sea water on the Pacific side, fresh water on the Atlantic side and atmospheric exposure on both the Pacific and Atlantic sides of the Isthmus.

The test project includes cold and hot bituminous coatings, inhibitive primers, oleoresinous, simple and compound synthetic resin and rubber type paints, and antifouling coatings which were suggested as suitable and durable protectives for metal structures on the Isthmus, particularly those of steel having large dimensions.

Limitations of testing activity facilities made it necessary to restrict an unlimited and diverse field of protective materials and protection problems by selecting only basic materials and conditions of test which would be useful and pertinent to maintenance repainting and construction of additional operating facilities directly related to the Panama Canal.

Selection was guided chiefly by recommendations deriving from directed inquiry to stateside and/or local government and industrial consumers, research organizations engaged in developing and evaluating and reputable manufacturers of protective coating materials.

The materials are being subjected to continuing inspections and observations to evaluate and assess performance behavior. It is contemplated that the tests will continue until the coatings have deteriorated to an extent that repainting is necessary to repair protection.

The information obtained from the tests is being used to arrange the various protective systems in an order based on merit which will make possible the selection of those which are outstandingly durable for final "job" proving by large-scale applications to various suitable steel structures for final testing and evaluation.

Conclusions. Within the limits of this investigation and the results presently reported for the first interim exposure period inspections covering a duration of one year for panel tests and two years for semi-large scale tests, it may be concluded that:

a) With reference to immersion tests,
   1) The sea water mean-tide environment appears to be the most aggressive exposure; the systems which resist degradation best in this environment apparently may be classed as vinyl antifouling, synthetic rubber, thiokol and phenolic types. Seventy-five percent of a total of 82 systems tested in this exposure could be designated as inferior at the end of one year.
   2) In the sea water continuous exposure, 16 percent of a total of 83 systems were definitely inferior at the end of one year and the greatest number were of the cold applied bituminous type.
   3) In the fresh water continuous exposure, 6 percent of a total of 65 systems were definitely inferior at the end of one year.

b) With reference to atmospheric tests at all exposure sites, 5 percent of a total of 67 systems showed definitely inferior performance at the end of one year.

c) Of the 12 systems included in the semi-large scale test and exposed in the marine atmospheric environment, Pacific side, two were inferior at the end of two years and both were of the cold applied bituminous type.

★This is summary and conclusion only of a report of the United States Panama Canal administration's Protective Coatings Investigation issued May, 1951.

* Engineering and Construction Bureau, Engineering Division, Balboa Heights, Canal Zone.

Part II of Two Parts

Prevention of Corrosion in Naval Aircraft *

By N. E. PROMISEL* and G. S. MUSTIN*

Part I of This Article Was Published in Corrosion, 7, No. 10, 339-352 (1951) Oct.

To take care of varying situations in the logistic support of aircraft several variants of the same basic preservation scheme have been developed. The use of the various types of engine preservation may be summarized as follows:

a) Type I Preservation is used primarily for operable engines where the length of storage is unknown to the station preparing the engine for storage. New and newly overhauled engines and operable engines being returned for overhaul are the ones most commonly preserved by these methods. The techniques of sealing the engine vary slightly depending on whether the engine is to be placed in a wooden box or metal container.

b) Type II Preservation is used primarily for those operable engines which are to be stored indoors for relatively short periods. These periods have been established at 30 days for reciprocating engines and 60 days for gas turbine engines. Major uses are for engines which have not passed final check and must be returned to the shops for minor repair and adjustment and for low time engines being transferred from one airplane to another.

c) Type III Preservation is for those engines which are to be stored undercover for ten days or less and is used primarily by squadrons making engine changes.

d) Type IV Preservation is intended for the built up power plant which may be stored for a considerable period prior to being installed in an airplane. It is essentially the same preservation as Type I-B except that no shipping container is used.
(Type V Preservation was a method applicable to the large number of engines remaining in the Pacific Area at the end of the war and is no longer used.)

e) Type VI Preservation is used for inoperable engines being prepared for shipment to overhaul or minor repair.

f) Type VII Preservation is used for aircraft engines which have been immersed in water as the result of crash landings and the like. It is essentially similar to Type VI except for emphasis on removing any internal water by preliminary use of water displacing preservative compound, specification MIL-C-972, Grade III.

The major steps of these preservations are summarized in Tables VII and VIII.

In spite of the impressive benefits and savings derived from preservation, it is in general, a complicated and costly procedure. Like all complicated procedures it is dependent upon the fallible human element. As to cost, this factor is difficult to establish accurately but when it is considered that engine containers alone, some of which are eighteen feet long and five to six feet in diameter, may cost as much as $1000, the total cost of the operation is extremely impressive when the costs of labor and other materials are included.

It is for this reason that the Bureau of Aeronautics has explored the possibilities of using vapor phase inhibitors in preserving aircraft engines. The acid combustion products seemed to have an adverse effect on the quality of the preservation obtained, however, and no attempts at this usage have been made by the services in the last few years. Two airlines, however, have recently reported successful results with the material using considerably greater quantities than had been used heretofore. It is therefore planned to make further extensive tests of the material in the near future.

5.3 *Aircraft Engines—Permanent Protection*

The performance life of an aircraft engine is measured in hours and it may take a year or more before a sufficient number of hours are accumulated to warrant overhaul. Even an airplane in an active combat squadron spends more time on the ground than it does in the air. For a considerable period, therefore, attention has been focused on providing better permanent protection to the engine while it was installed on the airplane. The protection should suffice during those short periods of idleness when application of even parts of the preservation technique described in Section 5.2 would be impractical and, possibly, should be sufficient to permit elimination of at least some of the preservation techniques. Preceding sections have discussed in some detail the problems inherent in many of the materials used in aircraft engines. The purpose of this section is to describe a few of the general problems that have been encountered and the reasons for the currently used solutions.

Corrosion in operating engines almost always occurs first in the cylinder area because of the high concentration of corrosive by-products. While a small amount of surface corrosion does no harm, the

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* Airborne Equipment Division, Bureau of Aeronautics, Department of the Navy, Washington, D. C.

TABLE VII—Partial Breakdown of Reciprocating Engine Preservations

OPERATION	Type I-A Extended Storage Metal Containers	Type I-B Extended Storage Wooden Containers	Type II Medium Storage	Type III Short Storage	Type VI Inoperable Engines
Corrosion Preventing Compound in Lubricating System	MIL-C-5545	MIL-C-5545	AN-VV-C-576	Engine Oil	MIL-C-5545
Run Engine 15 Mins. with Oil in Temp. between 95° and 102° C	Yes	Yes	Yes	Yes	No. Fill and Drain
Compound Injected at Shut Down	Yes	Yes	Yes	No	No
Drain and Dry Coolant System	Yes	Yes	Yes	No	Yes
Spray each Cylinder with Compound	Yes	Yes	Yes	No	Yes
Plug each Spark Plug—Opening with:	Screen Plug	Dehydrator Plug	Dehydrator Plug	Spark Plug	Same as I-A or I-B
Dehydrator Plug in Crank Case and Nose Sumps	No	Yes	Yes	No	Same as I-A or I-B
Preserve Spark Plug Terminal Sleeves	Yes	Yes	Yes	No	Yes
Preserve Fuel Feed Valve	Yes	Yes	No	No	Yes
Intake System Dehydrated	No	Yes	Yes	No	Same as I-A or I-B
Close Exhaust Ports or Stacks with:	Screen Plug or Dust Seal	Moisture Vapor Barrier	Moisture Vapor Barrier	No	Same as I-A or I-B
Close Air Intake Port with:	Ventilated Plate	Tight Gasketed Plate	Tight Gasketed Plate	No	Same as I-A or I-B
Accessory Drives Sprayed with Compound	Yes	Yes	No	No	Yes
Breather Openings Sealed	No	Yes	Yes	No	Same as I-A or I-B
Thrust Bearing Coated with Compound	Yes	Yes	No	No	Yes
Propeller Shaft Preserved AN-C-124 and Wrapped	Yes	Yes	Yes	Yes	Yes
Carburetor and Manifold Pressure Regulator Flushed with Grade 1065 Oil	Yes	Yes	No	No	Yes
Fuel and Water Pump Flushed with Grade 1065 Oil	Yes	Yes	No	No	Yes
Water Injection Equipment Preserved	Yes	Yes	No	No	Yes
Spark Plugs Preserved and Packaged	Yes	Yes	Yes	No	Yes
Engine Packed with Desiccant in:	Pressurized Metal Container	Flexible Barrier and Wood Box	No	No	Same as I-A or I-B

TABLE VIII

Partial Breakdown of Gas Turbine Engine Preservations

OPERATION	Type I-A Extended Storage	Type I-B Extended Storage	Type II Medium Storage	Type III Short Storage	Type VI In-operable
Corrosion Preventive Compound in. Lub. System (AN-VV-C-576: Lube OIL: : 3:1)	Yes	Yes	Yes	No	Yes
Run 5 Mins. at 75% Normal Rated Speed	Yes	Yes	Yes	Yes	No. Fill and Drain
Operate Afterburne 30 Seconds	Yes	Yes	Yes	Yes	No. Fill and Drain
Water Injection Equipment Preserved	Yes	Yes	Yes	No	Yes
Fuel System Flushed with Lubricating Oil	Yes	Yes	Yes	No	Yes
Breathers and Similar Openings Closed With:	Screened Closures	Tight Seals	Tight Seals	No	Same as I-A & I-B
Thrust Bearing Coated with Compound:	Yes	Yes	No	No	Yes
Propeller Shaft Coated AN-C-124 and Wrapped	Yes	Yes	Yes	Yes	Yes
Accessory Drives Coated with Compound	Yes	Yes	No	No	Yes
Engine Packed with Desiccant In:	Metal Container	M-V Barrier & Wooden Box	Nothing	Nothing	Same as I-A or I-B

development of a very small amount of pitting in the area of piston ring travel greatly increases ring wear leading to high oil consumption, a sometimes fatal disease on long over water missions. Serious pitting, especially if located opposite the cylinder hold down studs, leads to stress concentrations thus increasing the hazard of fracture of the cylinder wall or blow-off of the complete cylinder. The use of porous chromium plating to combat this condition on small engines has proven remarkably successful and is gradually being extended to all other engines. Adoption of the plating presents certain practical problems which require detailed study in each case and it is for this reason, primarily, that the changeover has not proceeded with the rapidity that might be desirable.

Another location where small amounts of corrosion pitting can lead to rapid failures is on internal steel parts such as gear teeth roots and in some cases connecting rods. Figure 13 is illustrative of the small amount of corrosion which occurs and yet, having occurred, renders an engine subject to major overhaul. Since the permissible loss of cross section is slight, parts replacement at overhaul of such an engine is high. During World War II it was found that the Germans were protecting the interior steel surfaces of aircraft engines with organic coatings with superior results. Most of the major paint companies cooperated in the hurried development of a phenolic resin coating obtained by the bake curing of a thin spray coat of a phenolic lacquer, now covered by Specification MIL-R-3043. Use of this material is now standard on practically all internal steel parts of aircraft engines except bearings and cylinder walls.

It is generally applied even to gear teeth. It rapidly wears off these surfaces, however, leaving them unprotected except by lubricant. The material worn off is so finely divided as to be almost undetectable in the lubricating oil.

The program in its present state has paid dividends and the material itself has demonstrated a high degree of improvement in protection afforded for numerous other applications. It is, for example, now being applied to domestic hardware. Its use in other aircraft applications is also being constantly expanded.

Table III lists one thin coat of phenolic resin as being class AA protection, equivalent to four coats of more standard finishes. In investigating the cause for the effectiveness of the material, much greater, as applied to bare steel, than would be anticipated from a knowledge of conventional finishes, it appeared that at least part of the explanation might lie in the dielectric effect of the material imposing a high electrical resistance between the adjacent metallographic constituents, rather than due to its performance as a highly impermeable water barrier.

Corrosion of internal and external magnesium and aluminum parts on aircraft engines has also occurred. Kirchner and Morris[3] have already mentioned a few of the more common locations. The manufacturers and the overhaul points are now converting to application of resin coating to practically all non-ferrous parts of engines in lieu of zinc chromate primer with excellent results. This is particularly true on compressor housings where conventional coatings have not exhibited satisfactory erosion resistance.

Application of the phenolic resin requires careful masking to prevent clogging oil holes or build up on close fitting surfaces, and the applied thickness must be held within close limits. The necessity for very careful training of personnel and the difficult in protecting close tolerance parts are inherent difficulties which have led to extensive investigation of other means of protection. Diffused cadmium—tin plating, phosphatizing and even black oxide treatments are among other common schemes used. All of these treatments have provided improvement over the bare condition, additional advantage, in the case of plated coatings, being galvanic protection of scratched and abraded areas, which of course, does not hold true for resin coatings. The phosphate treatments and plated coatings have been suspected because of possible embrittlement of the parts and there has been considerable question concerning whether phosphate treatments or oxide finishes were good enough. However, service tests have shown no difficulties attributable to embrittlement with either phosphate treatments or plated coatings, although it is not meant to imply that damage could not be done if applications were ill-chosen or the processing poorly done. The cadmium-tin plate has given consistently superior results and is considered the most desirable for steel parts. Many of the overhaul stations are now in the process of installing the necessary equipment and a gradual supplanting of the use of resin coating for internal steel parts is in process. The cadmium-tin coating possesses essentially the same anti-galling characteristics of the tin plate while being anodic to steel. Only very small quantities are required per engine. It has been estimated that less than 10 grams of cadmium and tin were required for a medium sized engine.

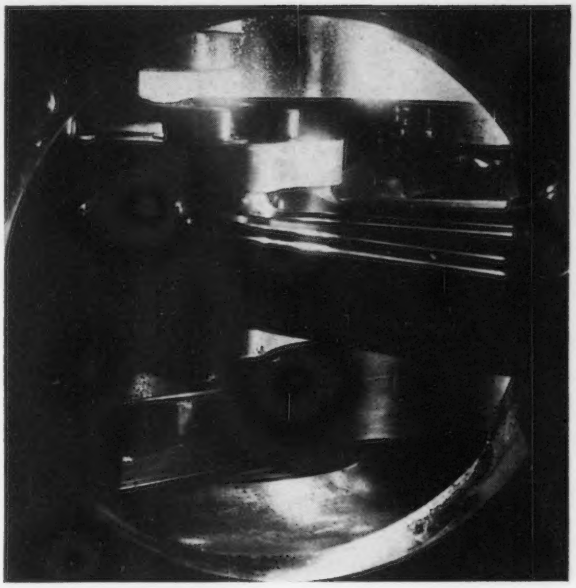

Figure 13—Corrosion on internal steel parts of an installed engine.

Corrosion on jet engines has been generally of the standard type in the "cold" sections of the engine. One noteworthy case has been surface corrosion of 12 per cent chromium steel used on compressor sections on an axial flow engine. During a period of intermittent operations with the airplanes spotted on the flight deck, corrosion occurred which required more than 50 manhours per engine to remove; a removal required to restore compressor efficiency. Such parts are now required to be nickel plated.

Aircraft engines have also had standard troubles with exterior corrosion, especially around the cadmium plated studs. It is standard practice to apply a coating of corrosion preventive compound of the AN-C-52 type to these studs where severe service is anticipated, such as on seaplanes. Considerable difficulties have been encountered with corrosion of the propeller shaft in the small area of this shaft exposed between the rear cone seat of the propeller and the front of the engine thrust nut cover plate. Although the amount of corrosion is slight it occurs in an area of high alternating stress and has caused many premature engine overhauls. In view of the excellent results achieved by cadmium-tin plating of these parts on small engines, extension of cadmium-tin plating of this area of the shaft to all engines is currently contemplated. The interim field fix involves careful tailoring of a cuff and use of just the right amount of corrosion preventive compound in the area. The technique must be carefully followed in order to prevent propeller looseness.

5.4 *Fretting Corrosion*

Wherever there is a combination of high unit loading and vibratory or oscillatory motion, fretting corrosion is a possibility. The effect of fretting corrosion,

as pointed out by Almen,[13] is to: 1) increase the susceptibility to fatigue failures of dynamically loaded machine elements; 2) destroy dimensional accuracy of closely fitted parts; and, 3) ruin bearing surfaces. There are still differences of opinion as to the exact mechanism of fretting corrosion but in a recent paper by Godfrey,[14] the following major conclusions were reached:

a) Fretting corrosion was caused by the removal of finely divided and apparently virgin material due to inherent adhesive forces.
b) The fretting corrosion of platinum, glass, quartz, ruby and mica relegated the role of oxidation as a cause to that of a secondary factor.
c) Fretting corrosion readily occurred between clean metals and non-metals. Glass microscope slides and steel balls provided an excellent method for observing fretting corrosion.
d) The initiating of fretting corrosion is independent of the frequency of vibration or the relative velocity.

An excellent practical survey of the problem is contained in Lubrication[15] and lists the seven methods which are most commonly used in operating mechanisms to eliminate the problem, which are:

a) Provision of an adequate lubricant or surface coating to reduce friction.
b) Provision of a plated or treated surface to increase friction and prevent slipping.
c) Provision of a gasket to absorb motion without metal pickup or welding.
d) Increasing the hardness of one or both surfaces.
e) Inducing residual compression stresses at the contact surfaces through shot peening, surface rolling, nitriding or carburizing.
f) Increasing motion in the operating region to a degree sufficient to maintain a protective lubricant film.
g) Elimination of oxygen at the interface.

The above methods assume that the load cannot be relieved and yet relief of the load is actually the most common method attempted and is frequently the most successful, particularly where the equipment is going to be idle as in the case of shipment of packaged goods. This is the specific method being used by some jet engine manufacturers who effectively prevent false brinelling of bearings by using a strongback at the end of the shaft so designed as to relieve the weight of the turbine shaft on the critical bearing.

Elimination or exclusion of oxygen is not attempted for the same reason that it is rarely attempted in any of the corrosion preventive operations undertaken. The gasket concept has proven successful through use of paper interleaving in the prevention of "traffic marks" occurring during shipment of bundled sheets of clad aluminum alloys. Increase in hardness has also been used, particularly in such applications as rocker arms, cam shafts and the like. Use of surface working, such as peening, is now a common design practice where difficulties are anticipated. It has worked well in helicopter transmissions where there is strong oscillatory motion as each rotor blade changes pitch during the course of each revolution.

Provision of adequate lubrication is sometimes a very difficult proposition since the high loads and high heats of friction, observed by Bowden[16] as reaching, on occasion, 1000 degrees C, contribute to deterioration of the lubricant itself. It is for this reason that molybdenum disulfide has attracted the attention of recent investigators. The basic characteristics of this material as a promising fretting corrosion inhibiting lubricant have been described in two papers by Godfrey and his co-workers.[17, 18] High temperature, high pressure and lubricating qualities of this material had been reported beginning in 1941 with structure reported in 1923 (See reference 17 for bibliography). It was reported in particular that, under the conditions of test described by Godfrey and Nelson, [17] a coating of molybdenum disulfide prevented onset of fret for 28 x 10^6 cycles as compared with onset of fret in less than 30 cycles on uncoated control specimens. These results have already led to the adoption of this material in a tail wheel installation on one airplane which was exhibiting severe galling even though existing service instructions called for daily lubrication. The use of molybdenum disulfide does not eliminate the need for oil or grease to prevent conventional corrosion.

It would appear that molybdenum disulfide offers great promise in preventing fretting corrosion where oscillatory motion is the main concern. It has not been adopted for aircraft control bearings pending further testing to determine the effect on ball bearings and because careful testing and selection of specific bearings and lubricants for specific applications has avoided difficulties.

Molybdenum disulfide also does not appear to be the final answer to the fretting corrosion which occurs in idle bearings which, under service conditions, would be in a fully operating condition such as engine bearings and that classic of the fretting corrosion picture, automobile wheel bearings.

Graphite has also been used as a fretting corrosion inhibitor but must be used with caution in aircraft work because of possible corrosion attack on light metals.

5.5 *High Temperature Materials*

Until recent years, elevated temperatures (i.e. temperatures above approximately 400 degrees F, for sake of simplicity) in aircraft existed in only a few places, mainly certain parts of the engine such as in the cylinder head, piston and related parts, particularly the valves, and in the exhaust system, and in auxiliary items such as heaters and heat-exchangers. The materials used were aluminum alloys for cylinder head and piston, chrome-nickel steels with tungsten or molybdenum for valves and 18-8 type stainless steels and Inconel for exhaust systems. In addition, valve seats were coated with hard-facing materials like Stellite No. 6 (a cobalt base alloy) which prevented surface attack to a great degree.

The past five years have seen the introduction of aircraft gas turbines (jets and turbo-props) and the attendant use, at elevated temperatures, of magne-

sium alloys (not greatly in excess of 400 degrees), ferritic steels (up to about 1000 degrees F) and a whole new series of oxidation-resisting materials for temperatures up to about 1800 degrees F. In this paper, guided missiles, rockets, aerodynamic heating and similar items will be ignored for the sake of brevity.

By and large, no unusual corrosion difficulties have been experienced at temperatures under 1000 degrees F, excluding possibly, indirect effects such as increased condensation at lower temperatures, already discussed, or accelerated reaction rate of normal corrosion processes at elevated temperatures. This will, therefore, be confined to materials and corrosion above approximately 1000 degrees F.

First with respect to exhaust systems, Inconel is rarely used any more, the predominating material being 18 chrome—8 nickel stainless steel, stabilized with either columbium or titanium (AISI Types 347 and 321 respectively). The corrosive products of combustion contain carbon dioxide, carbon monoxide, oxygen, hydrogen, nitrogen, hydrocarbons, lead salts and halides. Flame impingement, steep temperature gradients, vibration, thermal and mechanical stresses and relatively high gas velocities contribute to a situation requiring unusual properties in the material. The above steels have been remarkably successful, considering the stringent demands made on them. In a relatively small number of cases, which correspond to an extremely small percentage, two types of corrosion have been observed. One of these is intergranular attack and embrittlement, resulting from the formation of carbides in the grain boundaries. This susceptibility can be minimized by using sufficient stabilizer (titanium or columbium) in the steel or by preheating the steel to approximately 1600 degrees F for about ½ hour. The other type of corrosion is stress-corrosion, occurring under conditions, not completely understood as yet, of high residual or externally applied stress combined with a corrosive medium such as lead bromide in the exhaust gases. With both types of attack, the final result is a crack or fracture in the material, which itself might be the result of fatigue aggravated by the notch produced by the above attack.

While on the subject of stainless steel, it is well to emphasize the severely deleterious effect of zinc on this material at elevated temperatures. The effect is one of embrittlement, resulting from the intergranular penetration by the zinc, and is a function of both temperature and time at temperature, aggravated by stress. Suffice it to say that even traces of zinc can drastically embrittle stainless after a few hours at tempeatures as low as approximately 1000 degrees F. More moderate effects may appear at even lower temperatures, and longer times, and of course much more severe effects, even in much shorter times, at higher temperatures. Therefore, if any chance exists of a zinc coated part coming in contact with stainless with subsequent exposure to high temperature, the zinc should be replaced with cadmium, nickel or other suitable coatings. Zinc contamination from forming dies should be thoroughly removed.

It would not be appropriate to discuss in detail other high temperature materials and phenomena at this time, in view of the extensive treatment this subject would require. For strength purposes, these alloys in general contain appreciable amounts of chromium, nickel, and one or more of the following: cobalt, molybdenum, tungsten, columbium, titanium and iron. In general, the presence of the chrome and nickel (and often the other constituents) contribute a high degree of corrosion and oxidation resistance, with the result that corrosion does not normally occur. However, the existence of molybdenum may introduce a relatively novel corrosion phenomenon of itself. Molybdenum is readily oxidized to volatile MoO_3, which dissociates into MoO_2 and active oxygen. The latter then causes attack, often to such a severe degree as to be termed "catastrophic," particularly in confined areas where the MoO_3 vapors are not swept away. Molybdenum itself offers very attractive possibilities as a base for high-strength, high-temperature alloys but will require suitable protection before use. No completely satisfactory protective method has yet been developed, although diffused aluminum, silicon and possibly nickel coatings appear very promising.

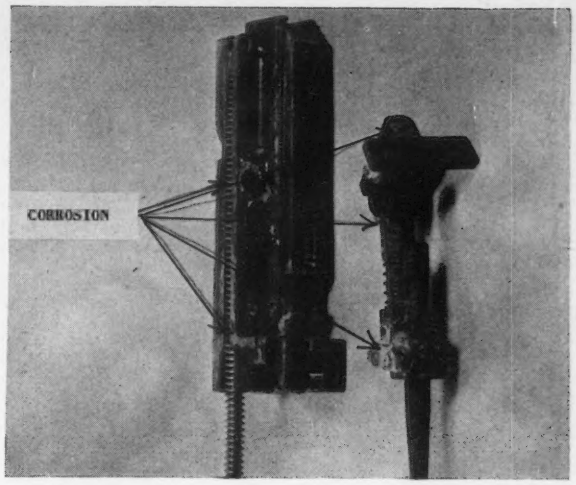

Figure 14—Corrosion of .30 calibre machine gun parts.

5.6 *Ordnance*

Before World War II, most aircraft ordnance was finished by "bluing." This practice was never too satisfactory, particularly under advanced base operating conditions. The present standard finish is usually one of the conventional phosphate coatings. Such a finish, when used alone, requires constant care and figure 14 illustrates failures which have occurred. However, even if the finish on the outside of the gun gave maximum protection, the barrel cannot be protected with a permanent finish, and it is generally this area, together with the breech mechanism, which is most subject to corrosion from primer salts.

It has been the practice, therefore, since guns were first used, to clean guns religiously after each firing and to place some type of oil in the mechanism as a rust preventive. For long term storage, heavier compounds were used and the advent of polar compounds has had its impact on gun preservation. To-

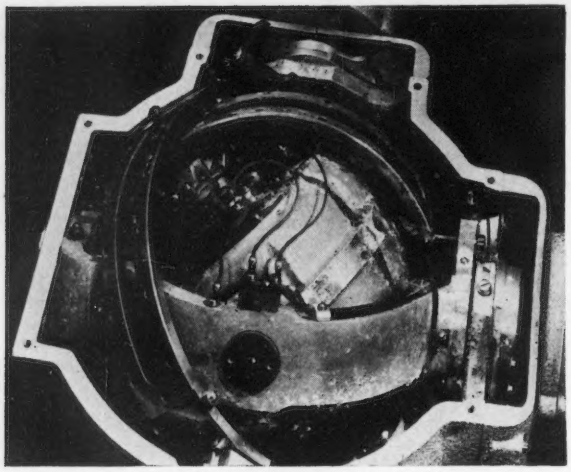

Figure 15—Corrosion of gyrostabilizing device.

day, guns are rarely left in aircraft for prolonged periods. After each firing, they are cleaned. The subsequent treatment of the gun will depend on the length of time anticipated before the next firing. Normally their treatment involves the use of additive oils, specifications MIL-L-644 or MIL-L-3150 for 3 and 10-30 day idleness with conventional packaging techniques being used for longer periods.

Other ordnance gear such as gun sights and bomb sights need careful protection. These are essentially computing mechanisms using mechanical and electronic techniques and their protection follows that of the electronic devices discussed below.

5.7 Electronics

Prior to World War II, the amount of electronics equipment carried in naval aircraft was relatively small. In the early days, the radios were specially designed for the purpose and were usually manufactured by a fairly small segment of the industry which was cognizant of the requirements of the Navy. In addition, it was not unusal for squadrons to remove radios from airplanes when on the ground in the tropics, and to keep them in hot lockers to prevent moisture and fungus damage. With tremendous wartime expansion of the industry plus very large increase in the numbers and types of electronics devices carried abroad, the situation changed drastically. Fungus damage to and corrosion of communications equipment during the early stages of the war was a very serious factor. Figure 15 is illustrative.

This situation necessitated and received wholehearted cooperation from all concerned. It is noteworthy that, by the end of the war, corrosion and fungus attack on installed airborne electronic equipment was almost a rarity. To accomplish this impressive achievement involved a major change in electronics material selection and manufacturing

TABLE IX—Partial Breakdown of Airplane Preservations

OPERATION	Type A Extended Storage-Standard	Type A Extended Storage-Desert	Type B 60 Day	Type C Low Freeboard Shipment	Type D 30 Day Fly Away	Type E 30 Day Combat	Type F 10 Day Fly Away	Type G 10 Day Combat	Type H Modification	Type J Overhaul
Lubricate Airplane	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Clean Airplane.....	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Fuel Tanks	Drain, Purge and Oil	Drain, Purge and Oil	Drain, Purge and Oil	Drain, Purge and Oil	Fill	Fill	Fill	Fill	Drain, Purge and Oil	Drain, Purge and Oil
Hydraulic Systems	Fill MIL-O-6083	Fill MIL-O-6083	Fill MIL-O-6083	Fill MIL-O-6083	Fill Reg. Fluid	Fill Reg. Fluid	Fill Reg. Fluid	Fill Reg. Fluid	Fill Reg. Fluid	No Action
Repair Corrosion and Touch Up Paint	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Engine Preservation—Reciproc.	Type I-A	Type I-B	Type I-B	Type I-A	Type II	Type II	Type III W/O Comp.	Type III W/O Comp.	Type III W/O Comp.	Type I-A or I-B
Eng. Preservation—Gas Turbine	Type I Complete	Type I Complete	Type II	Type II	Type II	Type II	Type III	Type III	Type III	Type I-A Complete
Coat Propeller Blades with	Heavy Grease	Heavy Grease	Heavy Grease	Heavy Grease	Oil	Oil	Oil	Oil	Oil	Heavy Grease
Battery.....	Remove	Remove	Chg. Disc.	Chg. Disc.	Chg. Disc.	Chg. Disc.	Chg. Disc.	Chg. Disc.	Chg. Disc.	Remove
Radio-Radar Units Covered	No	Yes	Yes	Yes	Yes	No	Yes	No	No	Remove
Ord. Preserved	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No	Yes or Remove
Photographic Preserved	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No	Yes or Remove
Exterior Bolts, Fittings, Cables, etc.	No	MIL-C-6708	AN-C-124	MIL-C-6708	AN-C-124	AN-C-124	AN-C-124	AN-C-124	No	AN-C-124
Oleo Struts	Deflate	Deflate *MIL-C-6708	Deflate *AN-C-124	Deflate *MIL-C-6708	Inflate *AN-VV-C-576	Inflate *AN-VV-C-576	Inflate	Inflate	No Action	Deflate *AN-C-124
Engine Exterior—Mg and Studs	No	Coat MIL-C-6708	Coat AN-VV-C-576	Coat MIL-C-6708	Coat AN-VV-C-576	Coat AN-VV-C-576	No	No	No	Coat AN-VV-C-576
Moving Unpainted Parts	No	Coat MIL-C-6708	Grease or AN-C-124	Coat MIL-C-6708	Grease or AN-C-124	Grease or AN-C-124	Grease or AN-C-124	Grease or AN-C-124	Grease or AN-C-124	Grease or AN-C-124
Exterior Unpainted Surfaces	No	Coat MIL-C-6708	Coat AN-C-124	Coat MIL-C-6708	No	No	No	No	No	No
Wheels	Remove	Remove Discs. Coat MIL-C-6708	No	Remove Discs. Coat MIL-C-6708	No	No	No	No	No	No

practices. The generally pertinent features, as they appear today, are essentially as follows:

a) Materials which are as corrosion proof and fungus proof as practicable are required for construction.

b) Each subassembly or component is required to be fungus and corrosion proof insofar as possible. Techniques of pressurizing with dry air or hermetically sealing the component are resorted to frequently if the unit is small enough so as not to require too rugged a casing for the allowable weight.

c) Electrical junctions are sealed with waterproofing compounds of the silicone type.

d) Moisture and fungus proof varnish, specification JAN-C-173, is applied liberally where other materials could not be applied without damage to electrical components.

e) Metal parts are, consistent with bonding requirements, finished with the same general finish schedules as the remainder of the airplane.

f) All components and assemblies are required to pass severe environmental tests before being released for use in the aircraft.

5.8 *Idle Aircraft*

From a military standpoint an airplane is a weapon with a fairly rapid obsolescence, a weapon which can become "war weary" in very short order. Further, an airplane that is second best in combat may be worse than no airplane at all since its presence may have promoted a false sense of security. It is essential, therefore, that there be a constant flow of new airplanes with all the latest improvements incorporated in them to the operating forces to replace operational and combat losses and to replace "war wearies." The operable aircraft retired from the arena are usually returned for reconditioning, incorporation of the latest changes and reuse.

It is also true of all military operations that maximum striking power must be available at the time it is needed. These factors conspire to insure that during the calendar life of a naval airplane (with some exceptions, e.g. transports in airline type operations) it is idle a great deal longer than it flies. While it is in storage and shipment much of the corrosion which has been discussed in this paper has a chance to reach serious proportions. Experience has shown that approximately ten general types of airplane preservation can take care of most situations. These complex procedures are briefed in Table IX.

The preferred method for general use is Type D, the medium preservation which requires a certain amount of maintenance but is not as difficult to apply or remove as types A through C but which, on the other hand, requires less maintenance than F or G. It can also be converted to the other types easily. Type D is applied to new aircraft as they leave the contractor's plant and stays on the airplane, unless other types of preservation are required for various reasons, until it is delivered to the squadron which will have operating custody.

Preservation maintenance procedures vary depending upon the type of treatment applied but, in most cases, test flight of the airplane at the end of the time limit given is required.

Airplanes in the various types of pools receive different types of preservation depending upon their status, the nature of the pool and the amount of personnel available for maintaining the preservation in a satisfactory status. Table X gives the general breakdown of the rules followed.

In Table IX only the corrosion preventive treatments applied to the airplane are listed. Specific action is also required to prevent or slow down the deterioration of the organic components of the airplane insofar as practicable. Another omission is in the final treatments given to Extended Storage Aircraft. The standard preservation for extended storage, Type A, involves storing the airplane in large sealed metal containers (actually made up from modified railroad car sections) under conditions of dynamic dehumidification. The containers average a capacity of six aircraft and four containers are interconnected to one 600 CFM dynamic dehumidification machine of the same general type used in the preservation of ships and capable of removing 7.7 lb. of water per hour at a pressure differential of four inches of mercury. Each can is further provided with several hundred pounds of bagged desiccant spread throughout the container to assist in the initial drydown and to act as "flywheel" during the diurnal variation in ambient temperature. These cans have proven remarkably successful in inhibiting the corrosion of aircraft stored over a period of several years. Many alumni of the cans are currently in combat service.

Where the airplane is too large to fit in these cans a variant of the procedure is used by which all openings in the aircraft are sealed with sprayable strippable compound, specification MIL-B-6030, suitable ducting is attached to insure proper air circulation, and a dynamic dehumidifier and flywheel charge are used. This variant was used for several large sea-

TABLE X—Preservation of Pool Aircraft

Type of Pool	Type Preservation	Remarks
Ready for Issue.....	D—30 Day Flyaway	See Note 1
Awaiting Transfer to Other Units	D—30 Day Flyaway	See Note 1
Awaiting Transfer to Overhaul	D—30 Day Flyaway, or C—Low Free board Shipment, or B—60 Day	See Note 2
Awaiting Overhaul	D—30 Day Flyaway, or C—Low Free board Shipment, or B—60 Day	See Note 2
Undergoing Overhaul...	J—Overhaul	See Note 3
Awaiting or Undergoing Minor Repair	D—30 Day Flyaway, or B—60 Day	See Note 4
Awaiting or Undergoing Modification	D—30 Day Flyaway, or B—60 Day	See Note 4
Longterm Storage	A—Extended Storage—Standard X—Extended Storage—Desert	See Note 5
Awaiting Disposition	D—30 Day Flyaway, or C—Low Freeboard Shipment, or B—60 Day	See Notes 1 and 2

Notes

1. B, F or G may also be used depending on anticipated period of idleness.
2. If airplane non-flyable and engine operable use B or C. Engine non-operable use B or C. Except type U1 should be applied to engine (see Tables 7 and 8).
3. Apply D immediately upon completion acceptance tests.
4. H may be used if idle period will not exceed 10 days.
5. X used only at Naval Air Facility, Litchfield Park, Arizona.

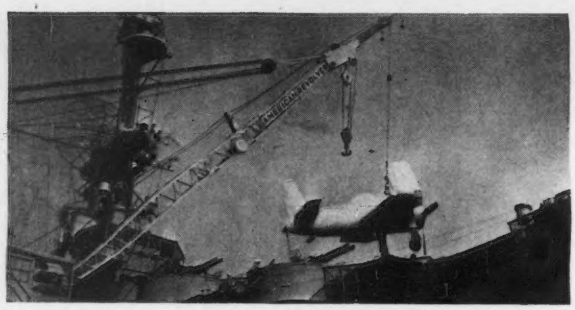

Figure 16—Service test of envelope preserving complete aircraft. Airplane being loaded for a sixty-day cruise.

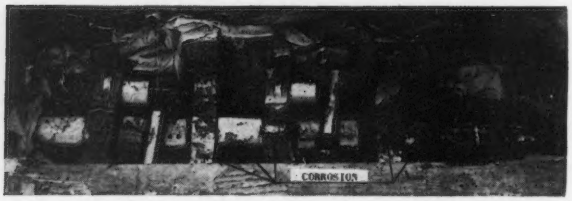

Figure 17—Corrosion of a spare crankshaft.

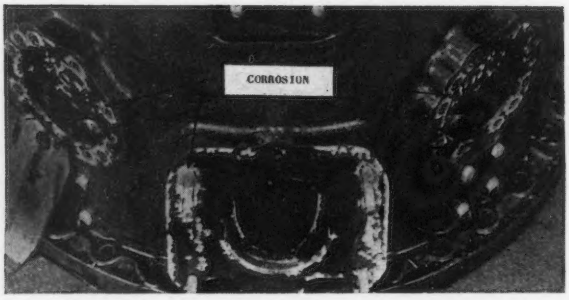

Figure 18—Corrosion of a spare engine nose section.

planes stored in the Seattle area for approximately two years. The activity removing the airplanes from storage reported that the condition of the airplane was excellent and similar to that of airplanes just coming out of overhaul.

Adoption of the two types of long term storage preservation discussed above was the result of a test conducted over approximately two years which definitely showed the protection afforded to be superior.

At the beginning of the long term storage program the number of huts built was determined by the anticipated number of airplanes to be stored. With the cutbacks of the entire program during 1948, a large excess of combat ready aircraft had to be stored, and the cans were already full. Accordingly, it was determined that the best place to store them in the open was in a desert location. In view of the general low relative humidity prevailing throughout the year, a slightly different type of preservation was chosen, now known as Type X, in which dehumidification of the entire airplane was not attempted but rather a procedure which would permit maximum ventilation. This procedure has worked remarkably well and, although more time is required to make the airplanes combat ready than the airplanes preserved Type A, it is considerably less than had been anticipated. Less than thirty manhours have been required on certain single engine aircraft to make them ready for flyaway delivery to modification centers.

TABLE XI—Breakdown of Spare Parts Preservation Methods

Designation	Description
I	Contact Preservative plus Greaseproof Wrap, Unsealed.
IA	Waterproof Package, with or without Contact Preservative.
IA-1	Tight Conforming Wrap Sealed with Microcrystalline Wax.
IA-2	Part Greaseproof Wrapped, Cartoned, Overwrapped, Wax Sealed.
IA-3	Part placed in Greaseproof Waterproof Bag and Sealed.
IA-4	Part Greaseproof Wrapped, Cartoned, Overwrapped Heavy Waterproof Paper, Glue Sealed.
IA-5	Rigid Metal Container, Sealed.
IA-6	Parts immersed in oil in Rigid Plastic or Metal Container.
IA-7	Vacuum Packing.
IA-8	Greaseproof, Waterproof, Water Vaporproof Bag, Sealed.
IA-9	Waterproof Bag, Sealed.
IA-10	Waterproof Fiberboard Metal End Cans.
IA-11	Special Water Resistant Fiberboard, Sealed.
IA-12	Container, Waterproof Compound Coated.
IB	Strippable Plastic.
IB-1	Plastic Applied direct.
IB-2	Part Wrapped Aluminum Foil, Strippable plastic.
IB-3	Part Wrapped Neutral Cotton, Strippable plastic.
II	Dehydration.
IIa	Floating Bag (i.e. bag loose on equipment).
IIb	Container-Barrier-Container.
IIc	Cushioned Item-Bag.
IId	Rigid Metal Container.
Unclassified	Migratory Inhibitors.
	Chemical Alone.
	Chemical deposited on wrapping paper.
	Chemical deposited on inner surface of carton.

The other types of preservation for severe or prolonged exposure, B and C, require a considerable number of manhours to apply and an equally large number to remove, a total of approximately 400 in the case of Type C. Even so, the degree of protection afforded, especially in the case of electronic components, is marginal. For this reason, studies have been under way on the possibility of adapating the techniques of dehydration to the complete airplane in such a manner as to permit shipment. Sprayable strippable plastics have been used occasionally for this work but are usable only once and are time consuming to apply and remove. Work has, therefore, been concentrated on a reusable envelope which would permit dehydration and is reaching a successful conclusion. Figure 16 illustrates an airplane so preserved being loaded aboard the flight deck of a carrier for a 60 day cruise. Upon return from this cruise the airplane was found to be free of corrosion. The basic preservation on the airplane was roughly equivalent to Type D except that breathing of cylinders was permitted. Application and removal of the entire preservation required less than 50 manhours.

5.9 *Spare Parts*

Global operations of naval aviation require global stocks of spare parts. The spare parts must be protected against the physical hazards of ocean shipment and handling at advanced bases together with superior protection against corrosion during a storage period of indefinite duration. At the beginning of World War II these facts were not fully appreciated by either the military or the industry, with decidedly unpleasant results. Figures 17 and 18 show typical examples of corrosion of spares occurring during this period.

Just prior to the war, during the period of expansion, attention had been invited to this problem of

spare parts by several field activities and some preliminary work had been started. Work was then accelerated in many laboratories and specialists in the problem were called in by all the services. By the end of the war a revolution in spare parts packaging had occurred and the problem of spare parts corrosion had been reduced to manageable proportions. Since the end of the war, development has continued in all phases of preservation and packaging with a view to improving existing techniques and with a view to developing packaging methods and materials which would also be suitable for arctic use.

Spare parts preservation and packaging for corrosion prevention purposes revolves, as does all corrosion preventive work, around control of the access of water to the surface. Figure 19 illustrates graphically the three basic methods used. Method IB, which is not shown, is a variant of IA in which a suitable strippable plastic, usually of the cellulose acetate butyrate type, is applied directly to the part for waterproofing and preservation. Table XI breaks these methods down in some detail to show most of the approved methods of achieving the performance desired. The use of these methods is given in detail in NavAer 00-85A-502, Handbook on Preservation, Packaging and Packing of Naval Aeronautical Material, now being converted to a joint Army, Navy, Air Force Manual.

The selection of the particular preservative compound and the particular method to be used depend upon numerous rather complex factors and the final success of whichever method is selected depends upon the care with which each step of the operation is carried out. Figure 20 illustrates this latter point. Method II Preservation was used but the operator failed to clean and dry the interior of the part thoroughly and then sealed in the moisture by using plugs in the openings. In the selection of preservative compounds, Table XII gives a breakdown of the preservatives which could be used and demonstrates the care and training of personnel needed to insure selection of the correct one for the particular part.

Considerable progress has been made in the last year towards simplifying the compound situation by combining them into one series of joint specifications. This work has been hampered by the problems of insuring reproducibility of test methods. For example, over two years of round robin tests on humidity cabinets of the AN-H-31 type produced disappointing results.

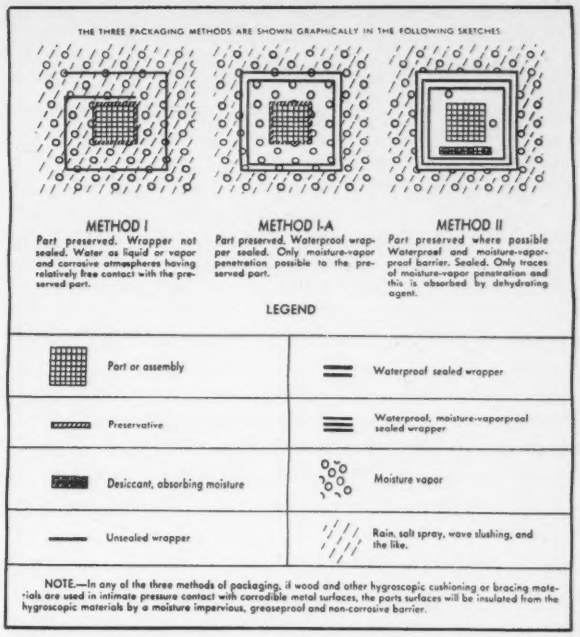
THE THREE PACKAGING METHODS ARE SHOWN GRAPHICALLY IN THE FOLLOWING SKETCHES
METHOD I
Part preserved. Wrapper not sealed. Water as liquid or vapor and corrosive atmospheres having relatively free contact with the preserved part.
METHOD I-A
Part preserved. Waterproof wrapper sealed. Only moisture-vapor penetration possible to the preserved part.
METHOD II
Part preserved where possible Waterproof and moisture-vaporproof barrier. Sealed. Only traces of moisture-vapor penetration and this is absorbed by dehydrating agent.
LEGEND
Part or assembly
Waterproof sealed wrapper
Preservative
Waterproof, moisture-vaporproof sealed wrapper
Desiccant, absorbing moisture
Moisture vapor
Unsealed wrapper
Rain, salt spray, wave slushing, and the like.
NOTE.—In any of the three methods of packaging, if wood and other hygroscopic cushioning or bracing materials are used in intimate pressure contact with corrodible metal surfaces, the parts surfaces will be insulated from the hygroscopic materials by a moisture impervious, greaseproof and non-corrosive barrier.

Figure 19—The three main methods of preservation.

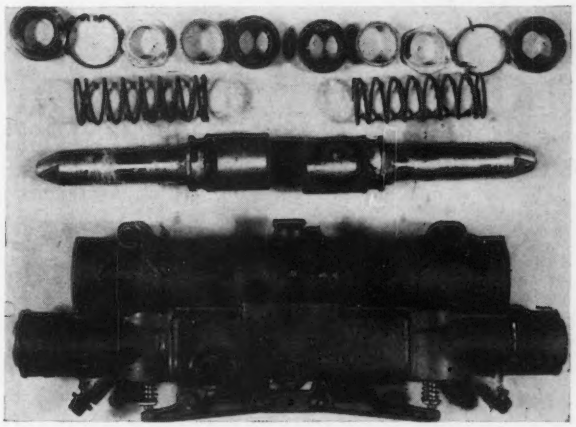

Figure 20—Results of improper preservation of master brake cylinder.

TABLE XII—Partial Listing of Preservatives

Army	Navy	Air Force Navy Aeronautical	Military	General Type
AXS-673	52-C-18, Grade I	AN-C-52 Type I	MIL-C-6708 MIL-C-972 (Ships)	Solvent Cutback petroleum wax with Polar additive, Hard Film.
.....	52-C-18, Grade II	AN-C-178	MIL-C-5545	Heavy Oil Type, Non-Drying
.....	52-C-18, Grade III	.....	MIL-C-972 (Ships)	Water Displacing
2-82	.....	.....	.....	Heavy Hot Dip Comp.
2-121	.....	AN-C-52, Type II	MIL-C-972 (Ships)	Med. Hot Dip
2-84	.....	.....	.....	Light Hot Dip
2-122	0S1363	.....	MIL-L-3150	Med. Pres. Oil
.....	14L17 (ORD) OS1362	.....	.....	Light Pres. Oil
2-120	051361	AN-O-6	MIL-L-644A	Special Pres. Oil
AXS-934	.....	AN-VV-C-576	MIL-	Engine Pres. Oil
AXS-1347	.....	AN-C-124, Type II	MIL-C-	Soft Film Comp.
.....	.....	AN-O-7	MIL-O-6083	Hydraulic System Pres.
AXS-1734	.....	AN-C-117	JAN-C-149	Hot Dip Strippable
.....	.....	AN-C-145	MIL-B-6030	Solvent Cut Vinyl Resin, Pigmented Sprayable Strippable
AXS-1719	MIL-R-15074 (Ships)	.....	.....	Compound, Corrosion, Preventive, Fingerprint Remover.
.....	.....	AN-O-11	.....	Synthetic Oil, Low Volatility

The general rules on the use of any of the methods of preservation are essentially as follows:

a.) Method I is applicable to relatively non-critical parts such as hand tools from which heavy preservative compounds need not be removed or from which removal of preservative compounds would not harm the part.
b.) Method IA with preservative compound is for critical parts from which the preservative compound can be removed without harm.
c.) Method IA without preservative compound is for non-critical parts which cannot withstand application or removal of preservative compounds.
d.) Method IB is the same as b above with the further proviso that the part must not be damaged by the heat of application of the melted preservative, 300 to 320 degrees F.
e.) Method II is for critical parts to which heavy preservative compounds cannot be applied or removed.

As stated above, the revolution of the last several years in spare parts packaging has reduced corrosion to manageable proportions. Many complex problems remain to be solved before the art of preservation can be considered an engineering discipline. Two problems have arisen in connection with the preservation of anti-friction bearings which are particularly pertinent to this paper because they illustrate the complexity which exists. It seems, incidentally, that almost all difficulties appear first on bearings and, if solved here, the lessons are directly applicable to other parts and equipment.

The first of these two problems concerns the inhibitive action of the preservative compounds, mainly of the AN-C-124, or AN-O-11 type on bearings. Both of these materials, before adoption, were exhaustively tested for protective qualities under conditions of high relative humidity (either in the AN-H-31 cabinet at 95 per cent RH or in the standard salt spray cabinet). Yet, in spite of success under these conditions corrosion of bearings preserved with AN-O-11 type oil reached epidemic proportions and several puzzling cases of corrosion in the heavier AN-C-124 material were noted. These corrosive conditions were duplicated in the laboratory at medium relative humidities (60 to 70 per cent) and, accordingly, the specifications have been modified to include corrosion tests in this humidity range. The actual mechanism here is not clear but it is suspected that the following two factors may be controlling:

a.) Additives are not pure chemicals and the lower molecular weight materials exhibit increased solvency in water, thus possibly permitting localized access of water to the surface. Improvements in preservative performance have been achieved by washing additives to remove water soluble salts.
b.) Sufficient water might not be present in the film to produce emulsion in the layers removed from the adsorbed interfacial layer. These emulsions would contribute to the performance of the preservative compound as a whole. Chisholm[18] has pointed out that the only explanation for improvement in performance of AN-O-7 over AN-O-6 lies in the presence of emulsifiers in the former material.

The other problem associated with bearing preservation is the so-called "incompatibility" of certain preservatives and greaseproof papers, i.e. a good paper and a good preservative causing corrosion in combination. This problem was recognized by Kunzenbacher of Hyatt Roller Bearing Division, General Motors Corporation, in the early stages of the bearing preservation program. Specific action to combat the possibility was not taken at the time because of the great urgency to achieve some improvement in an existing bad situation. In addition, a complicated series of round robin tests gave anomalous results albeit confirming that the possibility existed. The General Motors Corporation and the Forest Products Laboratory on behalf of the Air Materiel Command have been pursuing this matter further with somewhat disappointing results although empirical tests have shown definitely that the problem exists and that certain materials will work well together.

The mechanism of this "incompatibility" is not clear. It is believed that corrosion may be caused by one or more of the following factors:

a) Gradual drop in pH of the paper with age, leading to direct contact corrosion. The acidification of neutral greaseproof papers has been observed by practically all field activities conducting tests on materials in storage for any length of time.
b) Folding and creasing of the papers causing individual fibers to break through the greaseproof layer (frequently a resin impregnant or surface coating) thus drawing the preservative away from the part by wicking. This can be observed microscopically.
c) Preferential wetting of the greaseproof coating by the hydrophilic ends of polar additive molecules, thus leaving the metal surface bare for subsequent corrosion. This postulate lacks experimental verification.
d) The problem may be further complicated by the chemical and physical behavior of the compound itself, as previously discussed.

In addition to the troubles noted above, most of the current greaseproof papers are not greaseproof to the diester base oils and greases. Because of these two factors, therefore, most naval aircraft bearings are now preserved by wrapping them in aluminum foil, specification JAN-B-148. Staining of bearings so packaged has been reported by Air Materiel Command investigators but this staining is confined to the exterior portions of the bearing and does not normally affect its utility. Possible wartime shortages of aluminum foil require, however, that further work on the behavior of greaseproof barriers and preservative compounds be accomplished.

6. Anti-Corrosion Maintenance

The problems of corrosion prevention can only be carried a limited way by engineering personnel. Most of the preventing must be done by those in the field

charged with maintenance and storage. Without them, the best engineering is worthless. The purpose of this section is to outline the type of maintenance which is used and which contributes to the prevention of corrosion.

In the Navy it has been customary to insist on a clean, taut ship. While many polemics have been written against this custom, especially when it seemed to the uninitiated to approach the category of "make work," it is well to record that it results in tangible benefits of corrosion prevention as well as certain intangibles of morale, discipline and maximum readiness. Navy Regulations place the responsibility for the prevention of deterioration of material upon the physical custodian of such material. Thus, the procedures outlined herein, have the sanction not only of good common sense but of naval law and discipline. They stem from this ancient custom and, in their turn, strengthen it.

6.1 *Airplane Maintenance*

Frequent inspections of aircraft in the custody of operating units are required. The exact type of inspection performed depends upon the previous operating history of the airplane concerned. Each type of inspection varies slightly and calls for different actions depending upon the nature of the discrepancies which may be found. The detailed procedures for each inspection will also vary depending upon the airplane involved. In essence, however, the character and scope of the inspection may be summarized as follows:

a) Pre-flight Inspection—A visual inspection of the airplane with emphasis on safety of flight. Fuel tanks and strainers are drained to the extent necessary to remove any condensed water.
b) Post-flight Inspection—A security check on the airplane plus any items noted by the pilot. Also includes, in the case of seaplanes, a fresh water wash wherever practicable. Oleos are cleaned of dirt.
c) 30 Hour Inspection—A more detailed check of the equipment of the airplane. Access doors and plates are opened for visual inspection. Airplane is lubricated and cleaned superficially.
d) 60 Hour Inspection—Same as thirty hour but with more items to be checked and lubricated.
e) 120 Hour Inspection—A major visual check of all items of the airplane. Many accessories such as electronic gear are pulled for bench checks.
f) 240 Hour Inspection—A complete detailed structural inspection, with magnifying glass, of all parts of the airplane.

Fullest advantage is taken of each of the checks noted above to detect incipient corrosion and to take immediate remedial action to prevent further deterioration and to correct existing discrepancies. For a rough guide in the detailed items that must be checked particularly for corrosion, the Ten Day Preservations, as shown in Table IX should be consulted.

Whenever an operating activity finds that certain components of an aircraft are not regularly being used, these components are preserved in accordance with the general procedures shown in Table IX. For example, the guns are treated as outlined in section 5.6. Also, where water injection equipment has been used and reuse is not contemplated within ten days, the entire system must be preserved.

When, through restrictions on permissible flying hours per airplane or for other causes, it is not possible to operate an airplane at least once every ten days, the use of Type D or E Preservation (see Table IX) on such airplanes is mandatory. Airplanes may be maintained in this category almost indefinitely provided all discrepancies are promptly corrected.

In addition to the foreging, operating aircraft may be idle for many reasons and care is required to insure that corrosion does not commence during the period of idleness. In general, the reasons for idle periods can be divided into two broad general categories, as follows:

a) Idleness Due to Weekends and Holidays—These airplanes need only the minimum amount of care but the care must be provided. Assuming always that the policy with regard to partial preservation of components has been carried out, operating aircraft are prepared for this type of idleness through application of those portions of Type G preservation applicable to the engine and its accessories. If this period of idleness does not exceed four days, the propeller need be pulled through by hand on only one day of the idleness period. No airplane, however, may remain unflown for a period greater then ten days unless it has been preserved by one of the methods outlined for such periods of idleness.
b) Grounded Temporarily for Minor Repairs and Routine Checks—Because it is impossible to predict in every case how long such an aircraft will be grounded, due to the possibility of finding previously undetected discrepancies, application of one of the preservation procedures outlined in section 5.8 is mandatory in almost all cases.

6.2 *Spare Parts Maintenance*

Standard procedures promulgated by the Bureau of Aeronautics call for approximately monthly checks of all stocks of spare parts and equipment to insure that the material is in good condition and, in the interest of good business practice, to insure that excessive or unnecessary materials are not carried aboard. During these inspections, which are required to be made by personnel skilled in aircraft matters, sample packages are opened to determine the state of preservation of the contents.

In addition, a large number of the aircraft accessories items contain lubricants which will dry out with age or contain other highly perishable components such as rubber diaphragms, gaskets and packings. Specific storage lives for these components have been set after which the accessory is no longer considered ready for issue and must be checked and tested by a competent overhaul activity before being placed back in stock. This periodic checking of these

components permits ready repair of any corrosion which may have occurred and permits renewal of preservation.

6.3 *Repair Procedures*

Corrosion repair procedures used in naval aviation include all of those commonly employed elsewhere. In general, minor corrosion is repaired by removal of the corrosion product by any of the accepted means (with crocus cloth being preferred), passivation of the surface with chromic acid and touching up the paint. Severe corrosion, which is defined as corrosion sufficient to affect operation or safety, is usually repaired by replacement of the corroded part if not economically repairable. Moderate corrosion is repaired by reinforcing, adding doublers and other common structural techniques. Great care is taken to prevent pits becoming stress raisers by smoothing them out and fairing them carefully into the adjacent sound metal. Seed blasting and vapor blasting have proven most useful for this work. In repairing steel parts it is quite common to use chromium plating to return the part to its original dimensions. The actual amount of plating which is allowed to be applied varies with the part being treated and is under close engineering control.

7. Conclusions

An attempt has been made to show that, in spite of a very large number of corrosion producing conditions, practical solutions to corrosion problems have been achieved in naval aircraft. New problems are arising periodically and a number are anticipated as a result of new and rather unconventional designs and as a result of shortages of critical and strategic materials. These will be solved much as they have been solved in the past, by close attention to theory, application of known techniques and development of new techniques where necessary, and through the close cooperation of engineers, industrialists and maintenance personnel in the field. Some existing problems which require further research and development are:

a) Improvements in protective systems for magnesium alloys.
b) Coatings to permit application of molybdenum to aircraft.
c) Improved preservation techniques for aircraft, aircraft engines and spare parts for arctic purposes and for purposes of simplification and reducing costs.
d) Better corrosion test methods so that performance can be predicted with greater accuracy.
e) Substitutes for critical materials.

8. Acknowledgements

This paper presents facts, ideas and experiences compiled and collated from a number of sources over a period of years. The authors regret that time has not permitted detailed search of the literature to insure that proper credits are given in each case but gratefully acknowledge the work of all who have contributed to the present state of their knowledge. Particular acknowledgement is due to J. E. Sullivan, Director, Airborne Equipment Division, Bureau of Aeronautics, whose early work forms the basis for naval aircraft current corrosion prevention techniques and to S. L. Chisholm, Materials Engineer, Naval Air Station, San Diego, for gracious permission to paraphrase certain of his remarks made before a joint sectional symposium of the American Society of Metals and of the American Chemical Society, San Diego, September 15, 1950. The authors also acknowledge the technical and editorial advice and criticism given by their colleages, Lt. (jg) A. W. Skonberg USN and F. P. Somers, S. M. Collegeman, T. A. Johnston, H. R. Thoman, and T. F. Kearns.

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DISCUSSION

Question by Marc Darrin, Mutual Chemical Co., Baltimore, Md.:

Mr. Mustin showed a table where metals are arranged in groups along the line of the electromotive series—but based on "experience." I would like to know what is meant by "experience."

Authors' Reply:

The grouping of metals given in Air Force-Navy Standard Drawing AND10398, upon which Table VI is based was not based on the results of salt spray or similar accelerated tests. Much study has gone into the results of such testing and their implications in predicting service performance. We believe that almost all investigators feel that it is very dangerous to make firm predictions based on such tests alone.

The method of constructing the table was, rather, an application of electromotive series backed up by careful review of the frequency of various couples and the results which had been obtained with such couples in service. All of this was backed up with the realization that, for each couple, some form of protection, at least a shop coat of primer, could be expected to be present already so that the table can almost be interpreted as a definition of where more paint coats than normal will be required. The "frequency of occurrence" aspect of the table is very important. The very large number of metals in Group III are, from examination of their solution potentials, just as dissimilar to one another as are, for example, aluminum and magnesium. However, their chances of being couples are quite remote and our experience has been generally favorable.

It is emphasized that the groupings are intended for aircraft construction and are not necessarily applicable to any other structure. While similar tables

could probably be constructed to act as a rule-of-thumb in the design of other pieces of equipment, they would not necessarily be identical or even similar.

Question by George E. Best, Mutual Chemical Co., Baltimore, Md.:

Were the proprietary primers mentioned by Mr. Robinson of the wash primer type?
(Reply to this question is included in the following discussion).

Discussion by H. A. Robinson, The Dow Chemical Company, Midland, Mich.:

Good progress is being made in developing primers, paints and insulating practices for protecting magnesium components against bimetallic corrosion such as described by the authors. It is important first of all to recognize that galvanic corrosion involving magnesium can be effectively stopped by introducing enough resistance into the circuit of the corrosion cell. This may be accomplished by the application of suitable paint coatings and by means of insulating tapes or shims.

Salt-spray tests indicate that the chromate pigmented, government specification (ANP 656) primers currently employed on the faying surfaces of magnesium-dissimilar metal joints in aircraft, while satisfactory against general corrosion, are too porous and conductive to protect against galvanic corrosion for very long. Such primers must be fortified with one or more finish coats if electrical resistance sufficient to defer galvanic attack for a long time is to be developed. Much the same result can be obtained with primers alone by going to formulations having a vinyl chloride—vinyl acetate base. These primers apparently develop high electrical resistivity without recourse to finish coats.

Comparable results may also be obtained by the use of insulating tapes or shims which introduce resistance by lengthening the electrolytic leg of the corrosion cell circuit.

Authors' Reply:

The problem of minimizing corrosion of magnesium alloys under the severe conditons of service encountered by naval aircraft is a continuing one. The ideal solution is a truly waterproof, insulated joint. This can sometimes be approximated without using paint on the faying surfaces by mating carefully machined, fairly massive sections. Examples of the latter type are magneto mounting pads on engines and the relatively corrosion free bearing cone seat shown in Figure 8. Where such joints are not practical, a condition true of most aircraft construction, approaches to a waterproof joint can be achieved through use of rubber cements in the joint. This has the disadvantage of being messy and time consuming on the assembly floor. As mentioned by Mr. Robinson, tapes can also be used. They may be of the type used by electroplaters for stop-off purposes. Conventional zinc chromated tapes appear to be of little merit for this application. A distinct disadvantage to this technique will arise where any subsequent loosening of the joint cannot be tolerated. Finally, use of top coating material in the joint will improve the performance but not, in our opinion, as much as the two previously mentioned techniques.

In any case, however, it is essential that improved primers be developed and much work is going on in various service and private laboratories to this end. The definite promise of the vinyl co-polymer finishes is receiving the most careful attention. At least one of the formulations discussed by Mr. Robinson will receive service evaluation on experimental magnesium wings for a combat airplane.

Remarks by Otto E. Kirchner, American Air Lines, Tulsa, Okla.:

The related experiences of Messrs. Promisel and Mustin in their paper "Prevention of Corrosion in Naval Aircraft" concerning the effect of salt atmospheres on operating bases are very similar to those of American Airlines. At the time American Airlines considered moving their base from Chicago in 1939 to the then new North Beach Airport in New York (La Guardia Field), we were very much concerned over the problem of corrosion of inventory items, especially aluminum and magnesium parts. We had contacted several aircraft manufacturers located in the area to determine what special precautions were taken to avoid corrosion due to salt atmosphere. We were happily surprised to find that this conditon was restricted to a very narrow area along the shortline. One particular company—the manufacturer of floats—found it extremely satisfactory to store stock parts on the side of their hangar away from the waterline. No other protection was necessary. Our experience here at La Guardia has confirmed this earlier observation. We have found no unusual corrosion effects on our aircraft or on inventory items as a result of our operation from La Guardia Field.

Authors' Reply:

While we have noted distinct differences in the severity of corrosion encountered at Naval Air Station, Corpus Christi, which is on the waterfront, and some of its outlying fields which are several miles inland, detailed information is not available to us concerning the differences over narrower territorial areas. Kure Beach experience would appear to indicate caution for at least 1000 feet from the shore line with such items as prevailing wind, weather and height above the water being possible modifiers. A careful preliminary investigation of the type undertaken by American Airlines in the case of their move to La Guardia Field would appear indicated to prevent later grief.

Control of Sour Crude Corrosion In Kansas Production Operations ★

By L. C. CASE*

Abstract

The corrosive portion of Kansas oil fields covers generally all the area west of the Shoestring oil fields in the eastern part of the state. Within this area, the corrosion occurs mainly in wells producing from the Arbuckle limestone. Also, where serious corrosion occurs, there are certain common characteristics in chemical nature of well fluids and in the volumes of these fluids produced. In general, the brine is rather dilute, containing varying amounts of H_2S and CO_2. Release of acid gases from the produced brine brings about rise in pH and deposition of scale in surface equipment and in disposal wells. The oil also contains acid gases and has poor wetting ability. However, as a general rule, subsurface corrosion does not become particularly troublesome until water is about 85 percent of produced fluid. Relative importance of corrosion, as judged by equipment costs is, in descending order: tubing interior, rods, pump, casing exterior, tubing exterior and casing interior. Tabulation of subsurface costs, due to corrosion, indicate than an over-all average would be near $1800 per well year. The two most popular methods of corrosion control consist of down-hole introduction of oil wetting agents or formaldehyde. Comparison of before and after treating data indicates that these methods accomplish closely similar savings in equipment repair and costs of treating are also roughly equal. Testing costs average in the neighborhood of $120 per well year and corrosion is lessened by approximately 50 percent. The present corrosion prevention practice in Kansas has resultd from many years' experimentation with resistant materials and methods of well treatment. Experimental resistant materials have included plastic tubing, various alloy rods and tubing, galvanized tubing, plastic-coated and cement-lined tubing. Treating methods have included exclusion of possible oxygen, neutralization agents and protective scale in addition to the formaldehyde and oil wetting agents. A few materials, which probably should be classed as coating compounds, have received limited testing in laboratory and field. Their further development seems a distinct possibility.

L. C. CASE joined the Gulf Oil Corporation in 1925 to do research on subsurface oil-field waters. The many related water problems in oil production were gradually added to his work until corrosion also became included. Fourteen published articles exhibit this multiplication of endeavor from 1931 to 1950. In addition to NACE, he is a member of ACS, AAPG and AAAS.

Introduction

RATHER SEVERE corrosion of subsurface equipment in pumping wells has been experienced for a number of years in many Kansas oil fields. The corrosive area includes generally all fields in the central and western portions of the state which produce appreciable amounts of acid gases and relatively large volumes of water. See Figure 1. The oil fields of Greenwood County and others in eastern Kansas have little corrosion, probably due to differences in original reservoir conditions such as predominance of gas fields, production of relatively "sweeter" crudes from sandstone formations and less acid gas in the fluids produced from limestones. Where corrosion definitely exists in the fields of eastern Kansas it seems due, in many cases, to conditions induced by repressuring rather than to those inherent in the reservoir. For these reasons the fields of eastern Kansas will not be considered in this survey.

It is notable that nearly all production in the corrosive area comes from limestone. Additionally, the formation which causes most corrosion is the Arbuckle limestone which lies in direct contact with granite over much of the area. The Arbuckle limestone unfailingly produces much water as depletion progresses in an oil reservoir. Corrosion is evident in some wells producing from limestones which overlie the Arbuckle. For example, the Simpson, Viola, Hunton, Mississippi, and Kansas City limestones produce corrosive fluids in some fields. Thus the occurrence of corrosion is not strictly limited to the conditions peculiar to one geologic period or formation. Nevertheless, a general relationship exists in reservoir fluids produced in corrosive fields, regardless of all other differences in the producing formations. Water produced from the Arbuckle zone is rather closely similar over the entire area. Formation waters in the limestones above the Arbuckle vary widely but generally resemble Arbuckle water wherever corrosion exists. Because of this general relationship, it is believed that the characteristics of the corrosive water are indigenous to the Arbuckle limestone. Further, the similarity of water in corrosive wells producing from above the Arbuckle to that of the Arbuckle zone strongly indicates migration of reservoir fluids which resulted in common peculiarities in these reservoir fluids. In other words, Corrosion is concluded to be originally related to the Arbuckle lime and elsewhere it occurs in other reservoirs due to the movement of Arbuckle fluids into these reservoirs. An excellent example is found in the Gorham Pool, Range 14 South, Township 15 West, where water of the Kansas City limestone, of Pennsylvanian age, cannot be distinguished from water of the Arbuckle limestone, of Cambro-Ordovician age. Water of the upper formation should normally be a brine of approximately 150 grams per liter concentration, not containing hydrogen sulfide. At Gorham, the Pennsylvanian water is dilute and

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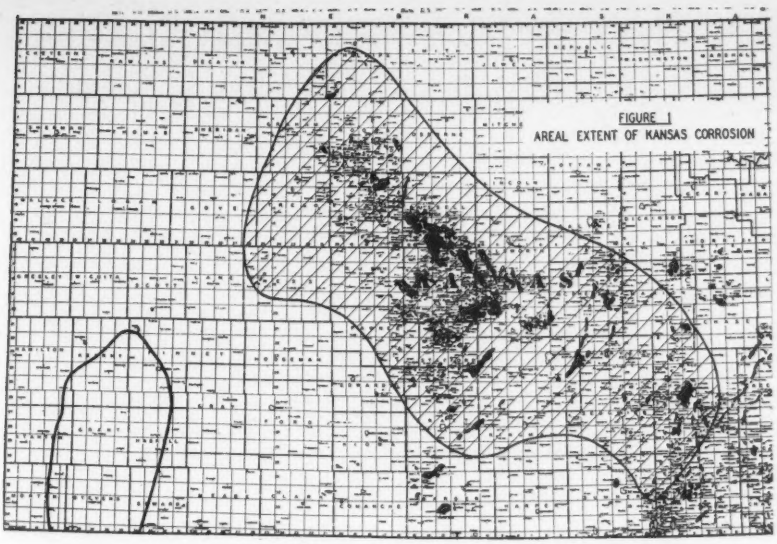

Figure 1

contains H_2S, as is characteristic of the Arbuckle zone. Obviously, fluids from the lower formation have moved along a contact zone, between sedimentary strata and underlying granite, until they reached a point where Kansas City limestone is in contact with the granite. From this point the migrating fluids moved laterally into the Kansas City lime for a distance of several miles. A number of closely similar relationships could be cited which lend strength to the theory that the Arbuckle limestone is the progenitor of corresponding, though lesser, corrosion evils in other oil zones. Fluids of the Arbuckle limestone will be described later to provide a basis for consideration of the general corrosion problem encountered in Kansas oil-producing operations.

Description of Pumping Well Corrosion

Some corrosion takes place on surface equipment but this is minor in comparison to that on subsurface equipment. The relative importance of corrosion, as judged by equipment replacement is, in order of decreasing importance: tubing interior, rods, pump, casing exterior, tubing exterior and casing interior. A major part of corrosion costs is due to corrosion attack on tubing interior. This may be described as a process involving a combination of chemical attack and "rod wear," whereby the tubing becomes grooved, to eventual complete penetration, along the approximate length of rod box movement. Such "rod wear" is not evident in non-corrosive wells and it is clearly caused by continuous removal of corrosion products by relatively light contact of the rod boxes. Considerable pitting is usually noticed, away from the grooved areas, but pits rarely penetrate the tubing wall. Corrosion attack is most common in the lower portion of the tubing string. However, exceptions occur where failures take place initially in the middle or upper part. No valid explanation has been found for corrosion rate occasionally being relatively greater in near-surface equipment. Many different grades of tubing have received thorough trial in Kansas fields. At present, tubing having most universal usage in the corrosive area is 2⅞-inch OD, 6.5 lb., 8 rd. th. EUE Seamless, Grade J-55. In severely corrosive wells, tubing failure may be expected within 4 to 7 months unless the wells are treated to minimize corrosion.

Failures of sucker rods, due to corrosion-fatigue, invariably present a closely similar pattern. Etched specimens from rods near the failures always reveal numerous pits with fatigue cracks at their bases. Considerable experimenting has been done with various rod strings in Kansas wells. Prior to successful down-the-hole anti-corrosion treatment, it was common to use much larger rods than should have been necessary under non-corrosive conditions. Usual rod installations, influenced in varying degrees by corrosion treatment and by changes in well productivities, are essentially tapered strings, ⅞-inch and ¾-inch, of the "4600 Series." Rod failures occur more frequently than tubing failures in some wells, less so in others. These rod breaks, originating from corrosion pits and subsequent fatigue cracks are believed by some observers to be a more trustworthy and earlier indication of corrosion and the necessity for preventive treatment than are tubing failures.

Pump failures, due to corrosion, occur less frequently than either tubing or rod troubles. Corroded plungers and barrels are noted about as often as valve trouble due to corrosion. Balls and seats usually fail by cracking before becoming noticeably pitted. Stainless steel, Type 440-B or 440-C, has been found to give best service in pump valves. Balls are almost invariably Type 440-C, while seats may be either type.

Exterior casing corrosion sometimes causes well leaks and major repair costs. Such leaks are rarely due to produced fluids but are caused by exterior contact of casing with brine of other formations above the oil zone. Interior casing and exterior tubing corrosion have been noted below the pump where "tail pipe" is used and the pump is set up the hole. Normally, with pump on bottom, tubing exterior and casing interior are protected by oil which accumulates naturally in the annulus during continuous pumping.

Methods of Corrosion Detection

Corrosion usually makes itself evident in pumping wells by way of rod or tubing failures before other methods of detection are effective. It is general practice to wait for such positive evidence of corrosion and then to apply other methods of equipment observation. In case of tubing failure, it is common procedure to run an internal tubing survey immediately following the second failure. This survey establishes the remaining thickness of tubing wall,

whether pits are large or small and replacements are made accordingly. Periodic use of the tubing survey and tubing "rotation" or replacement do not reduce the process of corrosion but the methods do reduce measureably the number of jobs and resulting labor costs. No systematic survey of this nature is yet applied to sucker rods. Instead, rods are changed in accordance with the number of breaks occurring and after visual inspection by field foremen or engineers.

Coupon assemblies have been used in Kansas pumping wells in an attempt to evaluate corrosion rate and effect of preventive treatment more quickly than is made possible by observations on equipment. "Flow line" or surface assemblies were initially tried. These consisted of a plastic bar with twenty mild steel plates attached, insulated both from one another and from the enclosing flow line. It was later found that ten plates gave equally dependable results but that the surface coupons do not ordinarily reflect the more rapid corrosion rate which occurs in the lower portions of well equipment. Therefore, a bottom-hole assembly was designed for installation below the pump. The bottom assembly consists of a length of perforated pipe to which is attached a rod holding ten round, mild steel coupons. The coupons are insulated by a plastic sleeve and by spacers. The perforated pipe screws into the hold-down, at the base of the pump, thus serving instead of a strainer nipple. These bottom coupons presently have two disadvantages. Rods and pump must be pulled in order to install or remove them. Also, the flow of fluid through the mud anchor and past the coupons is evidently not at all constant. It now seems established that the lower-most portion of the bottom assembly is often covered with semi-solid muck, in a static condition, and thus the lower coupons experience greatly exaggerated corrosion not typical of that occurring on any equipment further up the hole. This condition will be corrected by re-design of the bottom assembly and by placing it within the upper, or unperforated, portion of the strainer nipple.

Correct interpretation of combined data from surface and bottom coupons has been found useful in evaluating treating efficiency of experimental compounds. A period of six months to one year is required to establish the effect of a treatment on actual well equipment. The coupon data furnish a fairly reliable evaluation in approximately three months.

Nature of Kansas Well Fluids

Crude oil from the Arbuckle limestone in Kansas fields has a range of 18 degrees to 49 degrees API and is not saturated with gas. Very few wells have sufficient gas to flow initially. Sulfur content ranges from 0.15 to 0.69 percent. Fields producing relatively heavy, high sulfur oil do not usually show appreciable corrosion. The low gas content, more specifically acid gas content, of the heavy oil probably accounts for the limited corrosion. Arbuckle oil has been found to have little wetting ability in all fields where it has been tested. The data listed in Table I show that drops of the crude from four pools, in the heart of the corrosive area, are essentially spherical when tested in a medium of the well brine against a steel surface.

Brine produced with oil from the Arbuckle zone in Kansas varies from about 5 gm/liter total solids in northern fields to more than 150 gm/liter in southern fields. However, in central and western Kansas fields there is less variation in dissolved solids and other characteristics. In this area of closely spaced fields, the brine ranges typically from 20 to 40 gm/liter concentration. Hydrogen sulfide ranges from about 50 to 350 mgm/liter and pH is found to be near 6.3, measured at the wellhead. This brine is obviously in equilibrium with $CaCO_3$ in the limestone oil reservoir. Release of pressure, coincident with production, allows release of H_2S and CO_2, and consequent rise in pH. Thus, it is logical that pH at bottom-hole, before pressure release, is much lower than that observed at the surface. Preliminary calculations indicate that pH of the brine, within the reservoir, is near 5.5. Later investigation will establish this figure more accurately. The lower pH, existing at greater depth and pressure, is believed to account for accelerated corrosion rate near well bottom. The rise in pH of well brine following production is slow and progressive, approaching pH 8 when equilibrium is again established after several days' standing. The scale-forming tendency thus induced is successfully combatted by prevention of aeration or agitation within surface equipment. It is significant that corrosion is much less severe on surface equipment than on subsurface well equipment.

Gas from corrosive fields has been observed to range about 0.15 percent H_2S to somewhat above 8 percent by volume. Carbon dioxide may range as high as 4 percent by volume but is believed to average less than 1 percent by volume in the corrosive area. Where H_2S is low, CO_2 may be actually greater in amount. Where this occurs, severe corrosion may accompany a very low H_2S content. An approximate average condition is believed to exist in the Chase area of Rice County, where H_2S ranges from 1 percent to 2 percent and CO_2 is slightly less than 1 percent by volume.

Influence of Water: Oil Ratio and Other Factors on Corrosion Rate

The initial appearance of severe corrosion in western Kansas caused considerable concern and speculation as to the causes of corrosion. Early investigations included some attention to the possibility of air entry into casingheads and produced fluids. Field engineers reported that exterior tubing corrosion never affected more than the uppermost joints. However, tabulation of well data indicated that wells pro-

TABLE I

Wetting Power of Arbuckle Oil by Sessile Drop Method

POOL	Drop Ratio, $\frac{H}{\frac{1}{2}D}$
Chase	1.984
Chase	1.963
Silica	1.985
Silica	1.990
So. Silica	1.955
Keesling	1.970

ducing appreciable gas, from their open casingheads, experienced less corrosion than those making little or no gas. Wells making more gas were also noted to be making relatively less water than more corrosive wells. However, it seemed desirable to test the single effect of gas in keeping air out of the wells. Accordingly, casingheads were closed at a large number of wells to prevent any entry of air. The tabulation of well repair expense due to corrosion shows that nothing was accomplished by this expedient.

Since the accelerating effect of oxygen on acid gas corrosion is well known, it is concluded that air did not enter these wells prior to closing casingheads. Oil in the annuli should always contain H_2S, in excess of any oxygen which might enter. Thus, it would be patently impossible for air to enter fluid produced through the tubing unless it could channel through the oil column in a few hours. Field experiments proved that CCl_4, introduced into the casingheads, required 25 days to enter produced fluid even when wells were pumped continuously and 4.5 gal/day of oil-soluble chemical was injected in the annulus.

Early observations showed that wells producing "pipe line oil" never suffered appreciable corrosion. On the contrary, those producing large water volumes were usually experiencing corrosion difficulties. Laboratory work indicated that Arbuckle oil, in the presence of trace amounts of moisture, tended to be corrosive to steel. Further, the corrosion increased measureably with the appearance of appreciable water and again at about 80 percent water. See Figure 2. A tabulation of 48 corrosive wells showed also that subsurface equipment failures increased greatly when the water in produced fluid approached 85 percent. In some cases corrosion may be severe with much lower water percentages. On the contrary, some wells went appreciably above the 90 percent water figure before corrosion became troublesome. It is rather common practice to make preparations for well treating when water production approaches the average for the incidence of severe corrosion, namely 85 percent.

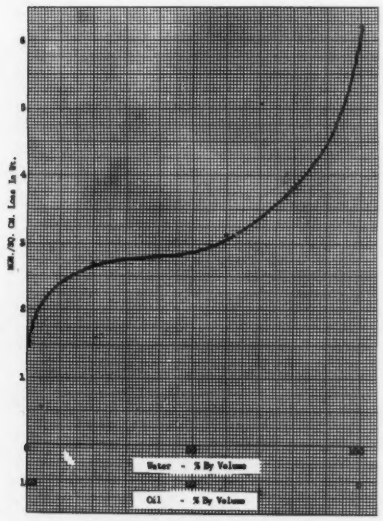

Figure 2—Effect of water on corrosion rate. Laboratory data. Shaking tests with varying proportions of Kansas (Arbuckle) Brine and Oil. 10-day period. 0.7 lb. H_2S pressure.

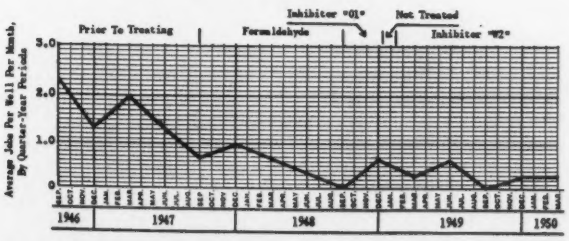

Figure 3—Experimental, daily anti-corrosion treatment. Typical well, Chase pool.

The concentration of H_2S in produced brine at corrosive wells is quite variable and apparently has no direct relationship to corrosion rate. It has been observed that 150 mgm/liter accompanies corrosion of equal severity to that where 350 mgm/liter is present. Carbon dioxide is also variable and in corrosive areas is usually less in percentage of produced gas than H_2S. Popular opinion, based on considerable field observation and limited laboratory investigation, seems to be that CO_2 causes less corrosion than H_2S, although CO_2 definitely contributes to the corrosion process. Lack of wetting power of the Arbuckle oil has already been shown.

In view of what is now known concerning corrosion in Kansas oil fields, it is concluded that the basic, major causes are, in descending order:

1) Production of water in excess of about 85 percent, provided acid gases are present.
2) Lack of wetting ability of the oil.
3) Presence of H_2S.
4) Presence of CO_2 in well fluids.

There seems to be no certain ratio of water: H_2S:CO_2 necessary for severe corrosion. In the absence of the acid gases, 95 percent water would probably not cause severe corrosion. However, at such high water level, the presence of an appreciable amount of either H_2S or CO_2 causes corrosion of subsurface well equipment. Within the corrosive area the acid gases are present in sufficient amount so that operators may expect corrosion coincident with water increase.

Corrosion Preventive Methods

Resistant materials were tried initially to combat corrosion in Kansas oil fields. Wrought iron and various alloy steels were used in tubing without appreciable success. Galvanized tubing was found also to add nothing to tubing life, although galvanized lease tanks have a rather good record in this area. Many non-metallic coatings have been tried, on both tubing and rods, but none has been found successful. Cement lining has a very good record in salt water disposal wells and in surface lead lines. Cement lining was tried in Kansas pumping wells with very disappointing results. It was found that failures of very small portions of the cement lining were suffi-

cient to foul the pump, necessitating expensive "stripping" jobs. Recently, plastic tubing was given a field trial in a salt water disposal well under normal operating conditions. After being in the well one week, the 3210-foot string of plastic tubing was pulled and it was found that 33 joints were collapsed due to external pressure of approximately 315 psi. Measured stretch in the string of 67 feet indicated present lack of creep resistance in this material. Evidently, much remains yet to be done before suitable and economical resistant materials can constitute a major factor in prevention of corrosion in Kansas oil fields.

Anti-Corrosion Well Treatment

Neutralization of acidic well fluid constituents presented an obvious and theoretically sound method of attack on the problem of pumping well corrosion. This method was given thorough field testing in the Eldorado area before 1930.[1] Down-hole treatment with caustic could no doubt lessen appreciably the corrosion rate on well equipment, provided that appreciable rise in pH might be effected without serious plugging due to scale formation. Thorough field trial showed that rapid fouling of pumps, due to scale, took place before appreciable difference could be noted in pH of water effluent at the wellhead.

The idea of protective scale occurred also as one having possibilities. Since sulfate occurs naturally in Arbuckle brine, it should be possible to deposit a coating of $BaSO_4$ on well equipment by continuous addition of $BaCl_2$ solution to the well annulus. This process was found to deposit a heavy, though discontinuous coating near well bottom and no coating at all near surface.

As corrosion became more troublesome in newer fields of western Kansas, it became evident that it would be necessary to find an effective anti-corrosion treatment in order to operate wells economically near depletion. Oil-soluble materials, which increase tendency of oil to wet steel surfaces, and additional permanence of these films, seemed to merit early field trial.[2] It is believed that naphthenic acid was the first compound of this general nature receiving serious investigation. Table III lists extensive field trials of caustic, $BaCl_2$ and naphthenic acid well treatment. All treatments were obvious failures. Results of the field tests with naphthenic acid were believed by some investigators to indicate that oil-soluble inhibitors would not be found practical in Kansas fields, due to the relatively low percentage of oil produced with the brine. However, the oil-soluble inhibitors were to receive definite development and application, which will be shown in the corrosion survey.

The first successful anti-corrosion treatment to achieve popularity, based on field performance, was daily, down-hole injection of formaldeyhyde.[3] Tabulation of field results with formaldehyde[4] showed conservatively that protection, in the order of 50 percent could be expected in Kansas fields. This degree of protection reflects a method both usable and economical when prevailing subsurface corrosion costs are considered. During the period when formaldehyde had no serious competitor, it was realized that it had several disadvantages.

1. It has a definite tendency to form emulsion and sludge.
2. Formaldehyde is a relatively heavy liquid and the amount required for well treatment caused transportation and handling difficulties.
3. The odor of formaldehyde and its reaction products are objectionable, when applying treatment or when pulling wells which have been treated with it.

For these reasons various investigators continued their efforts to develop oil-soluble inhibitors which would at least equal formaldehyde in minimizing corrosion rate and which would not possess the objectionable features. These efforts have culminated in considerable present field application of at least three different oil-soluble inhibitors which, as shown in the corrosion survey, account for a very large percentage of anti-corrosion well treatment in Kansas.

Experimental Anti-Corrosion Treatment

A great deal of information is now available concerning laboratory and field testing of formaldehyde and oil-soluble inhibitors. Field data indicate that protection from these materials is roughly equal, as are costs of the two treatments. Thus, standards are provided for comparison of experimental compounds, either water or oil miscible. Figure 3 illustrates comparative field results at one typically corrosive well, using three different methods of corrosion prevention. It should be kept in mind, when interpreting field data of this kind, that the effect of any one

TABLE II

Comparison of Corrosion Costs, Before and After Closing Casingheads at 25 Corrosive Wells.

12 Months Before Closing:	
Tubing	$ 6,679
Rods	2,900
Pumps	1,794
Total	$11,373
12 Months After Closing:	
Tubing	$ 9,472
Rods	2,197
Pumps	2,072
Total	$13,741

TABLE III

Comparison of Subsurface Costs, Due to Corrosion, Before and After Down-Hole Chemical Treatment of Western Kansas Wells.

	Caustic	Naphthenic Acid	Barium Chloride
Number of Wells Treated	16	2	2
BEFORE TREATMENT:			
Well Months Considered	837¾	99	97
Repair Exp. per Well per Mo.:			
Pump	$ 19	$ 17	$ 11
Tubing	78	87	38
Sucker Rods	31	29	6
Total	$128	$133	$ 55
AFTER TREATMENT:			
Well Months Considered	122¼	21	23
Repair Exp. per Well per Mo.:			
Pump	$ 25	$ 12	$ 47
Tubing	30	111	40
Sucker Rods	41	20	48
Total	$ 96	$143	$135

treatment, or absence of treatment, will be present in varying degrees in the period immediately following. For example, there is a definite "lag" in the effect of formaldehyde and again when type of treatment was changed radically to an oil-soluble compound. The delayed action of the no-treatment period also extends into the period when the effective, experimental compound was used. Figure 4 illustrates another field test, at three corrosive wells, where an unsuccessful compound was followed by one which was eminently successful but excessive in cost.

The search must continue until both more effective and more economical preventive methods are found for application in the Kansas fields. Some preliminary laboratory work has been done with the compounds which are proved effective bacteriocides and anti-corrosion agents in flood waters near Bradford, Pennsylvania. Two of these compounds indicate definitely greater protection, at about one-half concentration, of the standard or most-used materials. A comprehensive field trial is indicated at the conclusion of the laboratory screening tests.

Discussion of Inhibitors

The formaldehyde referred to in this report was invariably the "oil-field grade" which contains approximately 25 percent formaldehyde, 10 percent methyl alcohol and minor impurities such as formic acid, sodium, iron, manganese and sulfur. Hydrogen ion value is usually near 6.2.

The oil-soluble inhibitors were designated as "O1," "O2," and "O3" in Table IV and "O4" in Figue 4. Water-miscible inhibitors were shown as "W-1" on Figure 4, "W-2" on Figure 3, and as "W-3," "W-4" and "W-5" in Table IV. These inhibitors are described briefly as follows.

Inhibitor "O1" is an organic, semi-polar compound

TABLE IV
Corrosion Survey, Kansas Oil Wells West of Greenwood County

Company	No. Wells in Area	No. of Corrosive Wells	No. Wells Treated	TYPES TREATMENT, NO. WELLS FOR EACH					Estimated Percent Protection
				Formaldehyde	Oil-Soluble Inhibitor "01"	Oil-Soluble Inhibitor "02"	Oil-Soluble Inhibitor "03"	Other Methods[1]	
A	369	195	195	0	195	0	0	0	56
B	460	200	200	2	198	0	0	0	50+
C	198	111	104	91	11	2	0	0	67
D	560	200	116	0	116	0	0	0	55
E	58	58	58	58	0	0	0	0	62
F	718	385	352	333	19	0	0	0	55[2], 85[3]
G	134	95	95	0	95	0	0	0	46[4]
H	343	176	176	0	176	0	0	0	74
I	514	358	354	0	354	0	0	0	50-60
J	184	105	91	0	84	0	0	Plastic Tbg., 7	63[5]
K	1100	300	63	0	3	0	60	0	57, 70
L	613	149	149	1	148	0	0	0	63.6
M	392	202	202	2	180	0	0	"W-3", 16; "W-4", 2; Bimetal., 2;	75, 75, 75, 75, 25
N	480	295	295	0	291	0	0	"W-5", 4	25
O	686	465	439	0	439	0	0	Experimental, 4	80-90
Total....	6809	3294	2889	487[6]	2309[7]	2	60	35	....

[1] "W" designates experimental water-soluble inhibitors.
[2] Based on pulling costs and equipment replacement before and after treatment.
[3] Based on laboratory tests.
[4] Based on extensive field coupon data.
[5] Observed results on 84 wells.
[6] 16.8 percent of wells treated. Weighted average percent protection=58.
[7] 76.4 percent of wells treated. Weighted average percent protection=60.

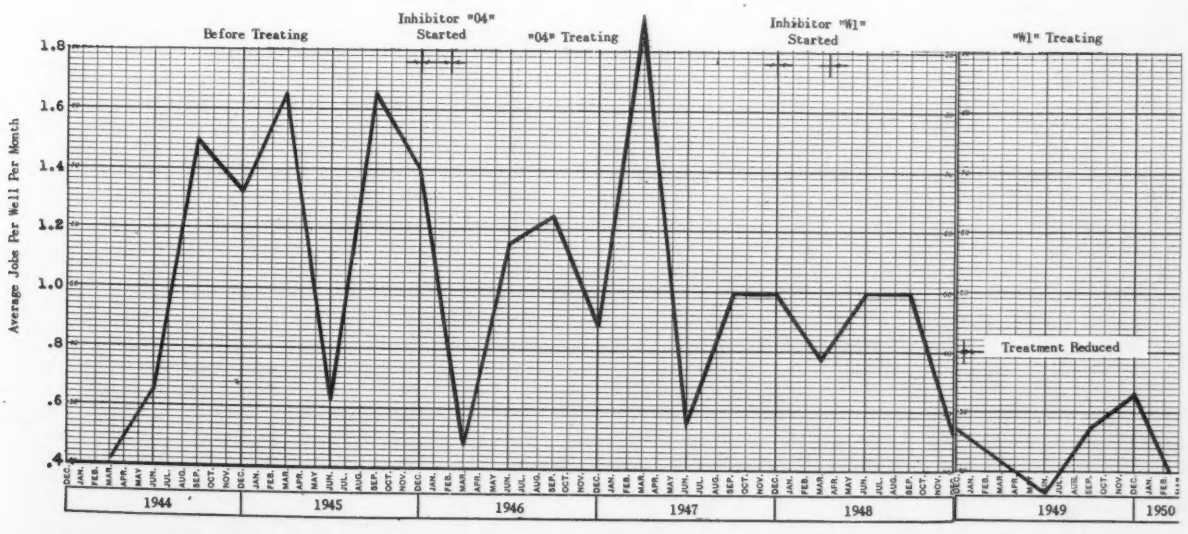

Figure 4—Experimental, daily well treatment, silica pool. Average jobs per well per month. (Three Arbuckle dolomite test wells).

of the heterocyclic, nitrogen-containing ring type. It does not strongly affect the wetting ability of oils and, therefore, is assumed to be film-forming in action. Inhibitor "O2" is a high molecular weight, oil-dispersible, organic compound. The "O3" inhibitor is an organic, oil-soluble, semi-polar, film-forming type which is understood to be structurally different from the preceding two. Experimental inhibitor ."O4" was composed essentially of sulfonated soya bean fatty acids, benzene and denaturing mixture.

Water-soluble inhibitor "W-1" is a polyoxyalkylene derivative of sorbitan monostearate. Inhibitor "W-2," as used in the field test, was mainly a water-miscible solvent which contained a clear material composed of carbon, hydrogen, oxygen and sulfur. The large amount of oxygen indicated water of hydration, either linkages or hydroxyl groups. "W-3" is the water-soluble equivalent of "O-1." "W-4" is a molecularly dehydrated polyphosphate. Nothing could be learned of the water-soluble inhibitor "W-5," because of its experimental status.

Summary

The severe oil well corrosion in the central and western Kansas area has been shown, in general, to accompany sour crude production. However, the sour crude is not, of itself, the cause of corrosion. Wells which produce "pipe line oil" never suffer appreciable corrosion, regardless of the acid gas content of the oil. The oil characteristically lacks wetting ability and, consequently, considerable corrosion occurs only after the appearance of appreciable water. The rate of corrosion attack accelerates sharply in the neighborhood of 80 or 85 percent water production.

The evolution of corrosion preventive methods has included resistant materials, neutralization, formaldehyde and oil-soluble inhibitors. A great deal of laboratory and field work has established the efficacy of formaldehyde and the oil-miscible materials. Success of the latter type of anti-corrosion well treatment was not predicted on the basis of low percentages of oil produced. Nevertheless, the "oily" inhibitors have proved successful in field practice and now constitute the most popular materials for corrosion control in Kansas oil fields.

Acknowledgments

The author wishes to thank the oil companies for their co-operation and release of information listed in the corrosion survey. Thanks are due also to E. C. Jacobson, Tulsa, for permission to publish the map of Kansas oil fields.

References

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3. U. S. Pat. 2,426,318, Aug. 26, 1947. Paul L. Menaul, assignor to the Stanolind Oil and Gas Co.
4. Walter C. Pearson, "Practical Results of a Planned Oil Well Corrosion Prevention Program in Western Kansas." A.P.I. Drilling and Prod. Practice, 1948, pp. 239-246.

DISCUSSION

(The author feels answers to questions posed hereunder where necessary and where information is available are answered in the text of the paper.)

Comment by H. E. Waldrip, Gulf Oil Corp., Houston, Texas:

For some time our laboratory has been studying the effects of acid gases on oil well brines. Carbon dioxide and hydrogen sulfide have been tested separately and in combination. The effects of these gases seem to be additive in lowering the pH of a brine. Bottom hole pH of from 0 to 2 units below that of well head pH have been determined. Tests indicate that the presence of carbon dioxide in sour brines lowers the rate of corrosion at a constant pH.

It is hoped that at some future date a paper will be written on this subject and that it may be possible to predict whether or not a well will become corrosive as the water production increases.

Question by J. N. Breston, Pennsylvania Crude Oil Association, Bradford, Pa.:

In your experience with the use of surface active agents for control of sour crude corrosion, have you noted whether there are any situations where an oil soluble agent would be more effective than a water soluble agent, or vice versa? Also, have you noted whether or not the produced water-to-oil ratio had any bearing on which of the two types of agent, water soluble or oil soluble, would be most effective in controlling corrosion?

Questions by H. C. Spalding, Jr., Sun Oil Co., Dallas, Texas:

Has any consistent relationship been found between the relative efficiency of water soluble (formaldehyde) inhibitors as compared to oil soluble inhibitors when plotted against water production? Efficiency of formaldehyde is given as 58 percent; efficiency of oil soluble inhibitors as 55 percent. Was there any indication water soluble inhibitors gave better protection at lower water production rates?

Corrosion Inhibition in Gas Condensate Wells By Intermittent Injection of Alkaline Solutions *

By CHARLES C. NATHAN

Purpose: The present report summarizes the results of experiments carried on by personnel of the Producing Research Laboratory of The Texas Company in efforts to reduce corrosion in gas condensate wells in which the casing is mudded off from the tubing.

A MAJOR PROBLEM in the operation of high pressure gas condensate wells in the Gulf Coast is occasioned by the corrosiveness of the produced fluids. Most of these wells produce small amounts of water (condensate, not brine) as well as liquid hydrocarbons and extensive corrosion often occurs in the tubing in the zone where liquid water exists. Investigations carried out during the past few years under the sponsorship of the Condensate Corrosion Committee of the Natural Gasoline Association of America have demonstrated the presence of carbon dioxide and fatty acids, e.g., acetic, propionic, etc. in the produced gases and liquids from these corrosive wells. Carbon dioxide and the lower molecular weight fatty acids are absorbed in the produced water, lowering its pH sufficiently to cause greatly accelerated corrosion of the tubing in zones where liquid water exists. Mitigation of corrosion in such wells has been effected by several methods. Among these methods are

1) use of resistant alloys, e.g., 9% nickel,
2) use of protective coatings,
3) addition of surface active materials which cause the metal surface to be preferentially oil-wet, thus preventing contact between the metal and acid containing water, and
4) use of water soluble materials which render the water film on the metal non-corrosive.

These water soluble materials may act through formation of a protective film on the metal, e.g., chromates and silicates or by raising the pH of the water film to a value sufficiently high to reduce markedly the rate of attack on the iron by the produced water. For raising the pH of the water film, various alkaline materials have been used, e.g., NaOH, Na_2CO_3, and $NaHCO_3$.

Background: Experience of other operators in the use of alkaline treating agents such as caustic soda and soda ash for the mitigation of gas condensate corrosion has been confirmed by the Producing Research Laboratory through work during the past two years in a deep gas condensate field in the Gulf Coast Area, Texas. Of four wells operated by The Texas Company in this field, two have open annuli through which chemicals may be pumped continuously. One of these wells, A, has been treated with a solution of sodium carbonate since August, 1949, at which time a caliper survey was run on the well. Subsequent caliper surveys in December 1949 and May 1950 have shown no measurable increase of corrosion in the tubing.

When flowing at their allowable production rates of about 4.5 MMCF of gas per day per well through 2 inch tubing, the wells in this field produce about 1.5 barrels of water per MMCF of gas. This produced

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Abstract

Experiments carried out by personnel of the Producing Research Laboratory of The Texas Company in efforts to reduce corrosion in deep gas condensate wells in the Gulf Coast area in which the casing is mudded off from the tubing indicate:

1. Of two wells with open annuli through which chemicals may be pumped, one well has been treated with sodium carbonate since August 1949 and has shown no measurable corrosion increases in the tubing in two caliper surveys.
2. Wells in the field produce about 1.5 barrels of water per MMCF of gas at their allowable rates of 4.5 MMCF daily. The water contains dissolved carbon dioxide and organic acids. Water collected at the surface has a pH of about 5.5 and contains about 130 PPM of dissolved iron. Lower flow rates produce water with higher pH and greater dissolved iron content.
3. Treatment of the well with 30 gal. per day of solution containing 2.5 lb. sal soda or sodium decahydrate per MMCF of produced gas costs approximately 15-20c per MMCF.
4. Kontol sticks dropped for one year in wells with closed annuli produced no measurable benefit.
5. Alkaline solution pumped intermittently into this well at the rate of 0.5 gal. per min. with sal soda dissolved in 10-20-gal. water had following results:
   a. At 4 MMCF a day iron content of water dropped rapidly to nearly zero, but rose in two hours to near original value.
   b. At 2 MMCF a day iron content dropped rapidly and is maintained at a very low rate for nearly 8 hours, then in about 4 hours content climbs to original value.
6. Data indicate alkali not being used up by reaction but is flushed from tubing walls by produced water.

Solution can be injected continuously into wells at any depth by another string of pipe.

* Submitted for publication January 4, 1951. Presented at South Central Region Meeting, National Association of Corrosion Engineers, Corpus Christi, Texas, October 19-20, 1951.

* Author's Note: Although alkalinity in Figure 2 is expressed as Na_2CO_3, percentages are based on total alkalinity to methyl red indicator.

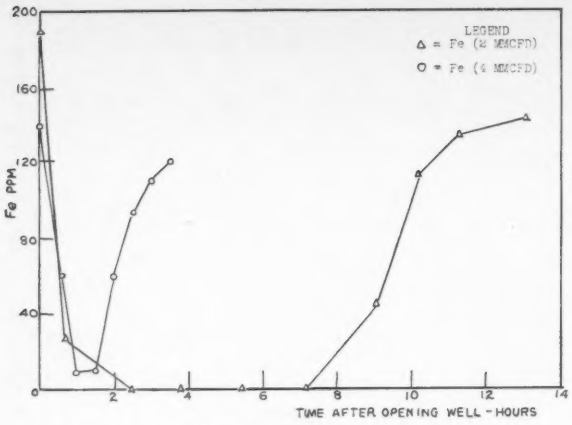

Figure 1

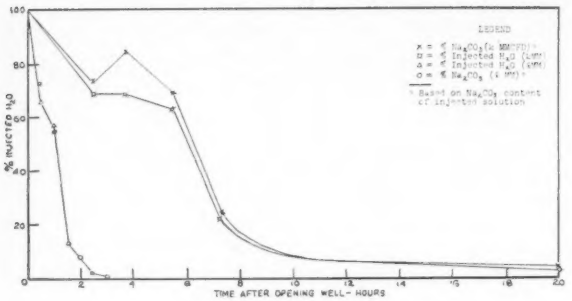

Figure 2

water contains dissolved carbon dioxide and organic acids, giving the water a low pH and accelerating the attack on the steel tubing walls. The water as collected at the surface has a pH of about 5.5, and contains about 130 PPM of dissolved iron. The pH of the water down the hole may be assumed to be considerably lower because of

1) increased solubility of carbon dioxide under pressure, and

2) presence of more unreacted acid with increasing depth.

When the well is flowed at lower rates, there is increased contact time between the produced water and the tubing walls and more of the dissolved acids react with the steel, so that the concentration of acids is less at the surface; hence the pH of the produced water is higher and the iron content also higher. Thus, a flow rate of about 1.5 MMCF per day gives a produced water of pH about 6.2 and containing 190 PPM of dissolved iron.

Treatment of the A well has consisted of the injection of about thirty gallons per day of a solution containing 2.5 pounds of sal soda or sodium carbonate decahydrate per MMCF of produced gas. The solution flows through the annulus through a side door choke into perforations in the tubing at about 10,400 feet and thence into the gas stream. When injection is maintained continuously and in the proper quantities, the produced water has a pH of about 7.2-7.4, and an iron content of less than 10 PPM. The expense of the treatment is approximately $0.15-$0.20 per MMCF.

Wells with Closed Annuli: It is not possible to inject chemicals continuously into the tubing of some other wells in this field, since the annuli are filled with mud. In one of these wells, B, Kontol sticks had been dropped into the tubing by means of a lubricator for about one year prior to the beginning of the present experiments. Caliper surveys showed no mitigation of corrosion, and indicated an actual increased rate. Dropping of the sticks was discontinued.

Use of Pumps: Because of the failure of the Kontol sticks, it was thought advisable to try pumping an alkaline solution intermittently into the tubing. Accordingly a high pressure, high-capacity pump was obtained, able to pump 0.5 gallons of liquid per minute against the well-head pressure of 4500 psi. Sal soda or washing soda was dissolved in 10-20 gallons of water, and pumped into the well and the well then turned on about a half hour after completion of the pumping. The amount of sal soda was varied from 10 to 20 pounds. Increasing the amount of sal soda to twenty pounds was no more effective than using only ten pounds.

Figure 1 shows the effect of injection of sal soda on the iron content of the produced water, as a function of time. The amount of injected solution contained in the produced water was also determined by the addition of salt to the injection water to act as a tracer and then by analyzing the produced water for chloride content. Data are shown for flow rates of approximately four and two MMCF per day. (See Figure 2.) The marked differences in the two sets of curves are easily seen. For the high flow rate, the iron content of the produced water rapidly falls to nearly zero, but also rapidly rises from the low value and within two to three hours is nearly back to its original value. The plot of percentage of injected solution in the water collected in the separator (Figure 2) shows that the injected solution is very quickly expelled from the tubing, practically none remaining at the end of three hours.

At the lower flow rate, it is seen that the iron content also falls to zero fairly rapidly, and is maintained at a very low rate for nearly eight hours, after which about four hours more are required before it again climbs to its original value. The plot of the percentage of injected solution in the collected water also verifies the prolonged effect of the treating solution The iron content rises when the percentage of injected solution falls below 25%. This occurs in about 7.5 hours for the 2 MM rate as compared to 1.5 hours for the 4 MM rate. After twenty-four hours the separator water still contains four per cent of the treating solution.

All the data seem to indicate that the solution is pumped at least as far down as the zone of condensation (about 6000 feet) as shown by the reduction in iron contents to zero and that the factor that controls the amount of time for which protection is obtained is the time required for the walls of the tubing to be scrubbed free of the alkaline solution which is protecting the walls. This time is very much dependent on the gas velocity. The cycle is apparently quadrupled by halving the flow rate or gas velocity. Data

for lower flow rates of about one MMCF per day are not as complete as for the other two rates, but indicate that protection is obtained for 24-36 hours after injection.

That the controlling factor is not the amount or strength of the alkaline solution is further shown by the plot of the alkalinity of the collected water as a function of time. The alkalinity* is plotted as the percentage of its value in the injected solution (Figure 2). The curves for percentage of alkalinity and percentage of injected water in the collected water are nearly coincident for the high flow rate and very close together for the low rate. These data indicate that the alkali is not being used up by reaction with the acidic materials in the gas stream but is merely being diluted and/or flushed out with the produced water. The alkaline solution clearly does not function as a neutralizing inhibitor in the sense of neutralizing all acid constituents produced in the well. This is also shown by experiments on well A where continuous injection is maintained. The ten pounds of sal soda added per day could neutralize only 1.5 pounds of CO_2, which is a very small percentage of the total amount produced in the well. The treatment evidently functions by keeping the tubing walls wet with an alkaline solution, and the only acids that need be neutralized are those which are dissolved in the small amount of produced water.

Field Application of Findings: The use of alkaline materials such as sodium hydroxide, carbonate, or bicarbonate has been said to be about the cheapest and easiest method of combatting gas condensate corrosion where it is possible to use this method. Our experience at the A well seems to confirm this statement. There are several advantages to continuous injection of the solution as compared to intermittent or slug-wise treatment. Among these are

1) lack of down time with loss of production,
2) uniformity of operating conditions, and
3) simplicity of operation.

An even more basic advantage is that injection of the material at the perforations or at some other point far down the hole places the chemical in the strongest concentration and amount at the zone of maximum corrosion where it is of the most benefit, as previously pointed out.

The solution can be injected continuously into the bottom of the tubing or at any other desired depth, by use of another string of pipe. The "macaroni" strings which have been tried by several operators with dubious success employ this string inside the tubing. It could also be placed in the annulus and connected onto the tubing at the desired depth. Such a method would eliminate any troubles which have been or may be encountered by parting of the macaroni string inside the tubing, with subsequent fishing jobs. If the external string fails, there would be no interference with production, although there would be no corrosion protection.

Another method of placing the alkaline solution at the zone of maximum corrosion would be the use of a bailer filled with the treating solution. This bailer would need to be equipped with proper devices for opening at the desired depth.

Other operators are presently treating wells by intermittent injection of sodium bicarbonate, with protection being afforded for something like 24 hours. These wells are flowing at rates of 1-3 MMCF per day through 2½-inch tubing. From the data here presented, it appears that the controlling factor in establishing length of protection is gas velocity of the flow stream. Probably, a protection time of eight hours is the minimum practical for field operation by regular personnel. Favorable conditions for use of the method appear to be:

1) Operation of wells at low flow rates.
2) Operation of wells employing 2½-inch tubing rather than 2-inch tubing. The larger tubing should allow a flow rate about 50% higher than the smaller for the same protection time.
3) Operation of wells at high tubing pressures. For a given flow rate, measured in SCF, the linear velocity of the gas stream should be inversely proportional to the average tubing pressure.

Discussions

Stress Corrosion Cracking in Alkaline Solutions. TP 5C-Sub-Surface Corrosion by Alkaline Solutions, By H. W. Schmidt, P. J. Gegner, C. F. Pogacar and E. H. Wyche. *Corrosion,* 7, No. 9, 295-302 (1951) September.

Question by Thomas F. Degnan, E. I. DuPont de Nemours & Co., Inc., Penns Grove, N.J.:

In view of your data showing failures of steel tanks at temperatures below about 130 degrees F in 30 percent caustic is it in your opinion a safe assumption that storage tanks at ambient temperatures need not be stress-relieved for 30 percent caustic service?

Reply by H. W. Schmidt:

From the available data and experience it can be concluded that storage tanks containing 30 percent caustic at around room temperature need not be stress-relieved.

Question by John L. McPherson, Blaw-Knox Construction Co., Pittsburgh, Pa.:

Where did failures occur in vessels cracking after several years' service? Could these failures have occurred because of support failure causing high stresses in tank?

Reply by H. W. Schmidt:

Failures occur at or near a weld or in an area subject to high stress. We do not believe failures occurred because of a tank support failure.

Questions by Leon D. Cook, Jr., Wyandotte Chemicals Corp., Wyandotte, Mich.:

1. Does any of the information obtained indicate any trend in the relative corrosiveness of electrolytic or lime soda caustic, or the effect of impurities present in the caustic on cracking tendencies?

2. Are there any materials known that may act as steel cracking inhibitors in caustic, such as silicates or nitrites or other soluble inorganic compounds?

3. Might there be information available on the cracking tendencies of steel in caustic as a function of oxidizing or reducing values of the caustic?

Reply by H. W. Schmidt:

The data do not show any difference between electrolytic or lime soda caustic as regards cracking. Effects of impurities are difficult to study since analysis is not available. W. C. Schraeder and A. A. Berk, Bureau of Mines Bulletin 443 "Intercrystalline Cracking of Boiler Steel and Its Prevention" show effects of various additions to caustic. In general silicates promote cracking. Sodium sulfate, phosphate and some organic materials like waste sulfite liquor seem to inhibit cracking.

Remarks by Clifford B. Armstrong, Jr., Wyandotte Chemicals Corp., Wyandotte, Mich.:

Referring to the question of corrosion inhibitors, recently an article has appeared concerning use of various inhibitors in railroad locomotives to reduce stress corrosion cracking. It was reported certain additive materials in recent years have reduced greatly the frequency of stress corrosion cracking in locomotives. I believe sodium nitrite was one of the materials used.

Question by C. S. Landau, Jr., National Analine Div., Allied Chemical and Dye Corp., Buffalo, N.Y.:

Did the investigation show any preference between internal and external heating coils for caustic storage tanks with respect to stress corrosion cracking?

Reply by H. W. Schmidt:

No. However, use of an external coil eliminates trouble of direct corrosion of coil itself.

Question by James B. Horton, Bethlehem, Pa.:

Do you have any data regarding susceptibility of various stainless steels to stress corrosion cracking in very hot caustic solutions?

Reply by H. W. Schmidt:

No data available.

Question by M. A. Scheil, A. O. Smith Corp., Milwaukee, Wis.:

Would it be the opinion or experience of the author that electroplated nickel coatings would be useful for protecting carbon steel against caustic embrittlement in several of the solutions that were mentioned in the paper? Does the author have information on the desirable plating thickness and whether this has been proven to be satisfactory under service conditions?

Authors' Reply:

Some of the questionnaires indicated that sprayed nickel coatings were effective in preventing cracking. It is the opinion of the authors that electroplated nickel coatings would also be effective but there are no data available to indicate the minimum plating thickness necessary.

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The Passivating Characteristics of the Stainless Steels. By W. G. Renshaw and J. A. Ferree. *Corrosion,* 7, No. 10, 353-360 (1951) Oct.

Questions by F. L. LaQue, International Nickel Company, New York:

1A. Were the samples held in air between measurements or kept in the measuring solution?

1B. Were the solutions aerated or agitated?

2. Was there any crevice corrosion under the paraffin?

3. How many specimens were represented by a particular point on the curves? Did the potentials remain constant during measurement?

4. Potential measurements didn't seem to reflect practical experience with the corrosion resistance and stability of passivity of the different compositions of the stainless steels under the circumstances of the tests.

Authors' Reply:

In all the investigations relating to air passivation specimens were held in air except at the instant when potential measurements were made. Where passivation in nitric, phosphoric and sodium hydroxide solution was involved, specimens were continuously held in these solutions after activation. No effort was made to aerate or agitate any of the solutions.

During the short exposure time of specimens in nitric, phosphoric or sodium hydroxide we did not note crevice corrosion beneath the paraffin, but we agree that it might occur after longer times in certain solutions.

In many instances only single samples were represented by a point on the curves, but in the case of chemical activation on the #2B surface and all passivation studies in solutions, at least two samples were employed.

Regarding Mr. LaQue's final comment we recognize that potential measurements do not necessarily reflect practical experience in every case. As an example of this we mention some work by Kiefer[1] on 18-8 material for pitting studies in ferric chloride and calcium hypochlorite. He found that a 4 percent chromic—4 percent hydrofluric acid treatment of 18-8 increased corrosion resistance of the metal very markedly in 10 percent ferric chloride solution over regular air passive samples, yet both samples showed the same potentials when measured in .1 normal sodium chloride. With air passive samples pitting occurred in eight to ten hours, while after the chromic-hydrofluoric treatment samples remained unattacked even at 72 hours.

This particular passivating solution is believed to remove certain surface constituents which might act as localized anodic areas subject to pitting with hypochlorite or chloride. Because these anodic spots are relatively small in reference to the total surface area, they do not have any significant effect on the average potential value. Thus the potential readings can be alike for two samples, yet their corrosion resistance can differ appreciably.

1. G. C. Kiefer, "The Passivation and Coloring of Stainless Steels," before 22nd Annual A.S.M. Convention, October 21-25, 1940. Published by A.S.M. in "Surface Treatment of Metals," 1941, pp. 20-32.

Question by H. H. Uhlig, Massachusetts Institute of Technology, Cambridge, Mass.:

The author's description of the nitric acid treatment as a cleaning procedure rather than a "passivating" process is in accord with the facts, and with recent theory. The improvement that results is essentially one of removing active areas such as specks of iron that have been rolled into the surface, and which can serve as pit nuclei. Hydrochloric acid containing a pickling inhibitor will do much the same thing, as was reported several years ago (H. H. Uhlig and E. M. Wallace, *Trans. Electrochem. Soc.* **81**, 511, 1942).

I can confirm Mr. LaQue's observations that potentials of stainless steels in aqueous media are variable, particularly after electrodes are first immersed. In experiments which we report later this week it required several hours to achieve a reasonably steady-state value in sodium chloride solution. This has been our general experience.

The observation of Mr. Renshaw of a logarithmic change of potential with time can also be explained by a logarithmic rate of physically adsorbed oxygen to chemisorbed oxygen. In fact the logarithmic rate is probably the one normally expected for a reaction of this kind. Since the observed change in potential should be linear with number of chemisorbed oxygen atoms on the surface, the potential would accordingly change linearly with logarithm of time as observed.

Authors' Reply:

We appreciate Mr. LaQue's and Dr. Uhlig's comments regarding the stability of potential readings upon immersion of specimens in solution, since this point is one which may present a problem to those who attempt to make such measurements on any metals. In our studies we found our potential values to be constant during the period of measurement except in some instances where initial fluctuation, which ceased in a matter of seconds, occurred.

Some mention of the measuring equipment we used might be worthwhile. For years we tried various types of instruments for potential studies and always encountered marked drifts when trying to take readings when ordinary voltmeters or potentiometers were used. We finally arrived at the following setup which avoids current flow such as might be encountered in balancing of potentiometers employed with or without vacuum tube circuits. The equipment we use also makes possible instantaneous readings which are therefore not clouded by polarization effects.

Essentially the operation is as follows (see Figure 1): A grid bias is placed on the tube such that current is permitted to flow to the plate with the tube

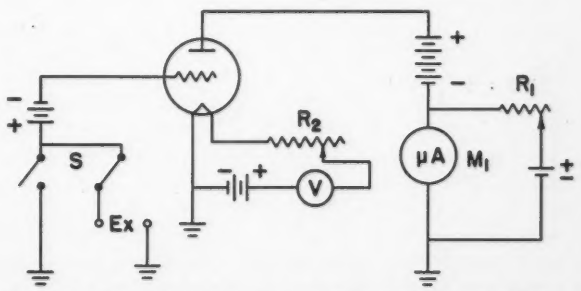

Figure 1—Wiring Diagram for Vacuum Tube Voltemeter. Switch S, so arranged that unknown potential Ex is thrown into grid circuit only at instant of measurement. With only grid bias applied to tube, R_1 is adjusted until M_1 shows zero current. When Ex is added on grid the current reading is noted on M_1, and value of Ex can be determined from calibration curve.

operating on the straight line portion of the Eg-Ip curve. By introducing into the plate circuit a current directly opposite to that flowing through the tube, it is possible to adjust the plate current microammeter to zero. When an unknown emf is added onto the grid bias, there is a change in the plate current reading. Previous calibration with known potentials applied on the grid makes it possible to determine unknowns from the microammeter readings.

Our experience with this measuring device indicates that constant, reproducible readings can be obtained for a cell even though they are made at widely different times. Using this equipment we were able to obtain stable potential readings with the stainless steels. In instances where slight initial fluctuations during measuring occurred, the readings for all purposes were instantaneous in that a constant value was reached within a few seconds. These fluctuations (which may be in either direction) are probably due to mechanical characteristics of the meter itself or due to variations in the wetting of the surface following immersion. Regardless, however, all readings are within a matter of a few seconds, constant and remain so during measurement. Provided stable surface conditions exist in the cell being measured, no persistent drift or instability of potential occurs such as suggested by Mr. LaQue's or Dr. Uhlig's comments.

In potential measurements on freshly activated samples readings were taken as soon as possible following immersion in the electrolyte. Obviously a freshly activated specimen does not possess a stable surface condition and will proceed to passivate rapidly at first. Early potential measurements, particularly in the first few minutes after activation, would naturally show a constant tendency toward the more passive state even in the measuring solution, but this it is to be expected and cannot be considered an instability of the readings. Since the electrolyte itself is capable of causing passivation of activated specimens at the same rate as in air it is apparent that the specimen would continue to passivate during measurement. If it were possible to employ an electrolyte which would neither activate nor passivate, we believe that all potentials would remain constant during readings.

After the specimen has been exposed for some time to air and has had an opportunity to become passive, it can be immersed in the measuring solution for long periods of time with the potential remaining constant indefinitely. That six different types of stainless steel, plotted on the same figure (Figure 4, Sandblasted Only), all show about the same potentials after the same passivation time in air is ample proof that readings are stable during measurement. It is also significant that the tests on different steels were conducted at different times.

Question by H. W. Schmidt, Dow Chemical Company, Midland, Mich.:

Assume we have a reasonably passive surface as evidenced by good corrosion resistance in a corrosion medium. We now activate the surface in HCl and replace the stainless steel in the original corrosive medium. What will happen? Will the surface remain active or become passive?

Authors' Reply:

If the particular medium is responsible for promoting or maintaining the passive condition of the stainless steel as shown by continuous good service, the surface would be expected to passivate again even after activation by hydrochloric acid. Where, of course, an active-passive borderline condition is encountered in the corrosive medium, activation with hydrochloric acid could result in attack of the stainless steel when replaced in the original solution since conditions would not then be sufficiently oxidizing to cause passivation.

Question by Mr. Garland M. Riegel, Republic Steel Corporation:

What was the composition of the electropolishing solution?

Electropolishing usually gives a very good finish or surface anyhow.

Author's Reply:

The electropolishing solution employed for these tests was a phosphoric acid solution containing approximately 70 percent by weight of acid at 140-150 degrees F.

Question by Mr. L. M. Nieliwocki, Sabine River Works, E. I. duPont de Nemours Co.:

What is your recommendation on how to effectively passivate austenitic stainless steels for general corrosion resistance?

Authors' Reply:

For general corrosion resistance there is no better passivating agent than air. In order to assure that air has the best possible chance to accomplish this, the surface of the stainless steel should be clean and free from scale. The usual pickling treatments employed with stainless steels during processing will accomplish this, or a treatment with 20 percent—40 percent warm nitric acid after machining or other fabricating operations is also effective in cleaning the metal, particularly in removing iron contamination from tools, etc.

Question by Roy V. Comeaux, Humble Oil & Refining Company:

The potential-time curves presented by the speaker indicate that the active areas become passivated on exposure to air. If stainless steel were exposed to a corrosive medium before sufficient time had elapsed to completely passivate all areas would pitting-type corrosion occur? The potential data indicate that the time required for complete passivation by exposure to air is greater than the downtime of some industrial process equipment. Is there some means other than the use of 30 percent HNO_3 of passivating the surface? Such a procedure would have to be easily applied, the cost would also have to be nominal.

Authors' Reply:

We would not expect pitting type of attack on

partially passivated stainless steel, unless the particular corrosive medium were one such as chloride solution capable of producing pitting. If the corrosive medium represents an active-passive borderline case, but is not a pitting agent, more likely a general overall type of attack will occur for reasons as mentioned in reply to Mr. Schmidt's question about activation.

As far as industrial process equipment is concerned, stainless steel is not usually recommended unless the corrosive medium handled is capable of promoting and maintaining a passive surface on the metal during service. Thus, regardless of short downtime periods, passivation would be attained during actual service, even if activation occurs during cleaning or other operations during shut-down.

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Rosin Amine-Ethylene Oxide Condensates as Corrosion Inhibitors for Mild Steel in Hydrochloric Acid. By Edward A. Bried and Harry M. Winn. *Corrosion*, 7, No. 6, 180-185 (1951) June.

Question by C. S. Brown, General Aniline & Film Corp., Grasselli, N. J.:

I requested information on the efficacy of these inhibitors in sulfuric and phosphoric acids.

Based on laboratory tests performed by the writer with a Rosin Amine-Ethylene Oxide Condensate manufactured by General Aniline and Film Corporation, these materials have excellent corrosion inhibitory power in 10 percent acid when pickling steel.

I. At 75° C in 10% HCl	Inches Per Year
Attack on steel—no inhibitor	: 2.3 IPY
Attack on steel—1500 ppm of a Com. Inhibitor	: 0.29 IPY
Attack on steel—1500 ppm Et. OX-Ros. Am.	: 0.18 IPY
II. At Boiling in 10% HCl.	
Attack on steel—no inhibitor	: 10.0 IPY
Attack on steel—1500 ppm Com. Inhibitor	. 1.22 IPY
Attack on steel—1500 ppm Et.OX-Ros. Am.	: 0.77 IPY

At both temperatures, the ethylene oxide rosin amine inhibitor reduced attack by 92 percent.

At General Aniline & Film's Grasselli, New Jersey plant, we have pickled process equipment with 10 percent hydrochloric acid and 1500 ppm of this inhibitor at the boiling point. The ability of the inhibitor to decrease surface tension and to wet rust and salt scale coupled with the bubbling and effervescence of the boiling solution and the nascent hydrogen gave much more de-scaling in half the time. No excessive attack due to the boiling acid could be observed in the equipment, either just after pickling or after return to operation.

Authors' Reply:

Very little work has been done by the authors on the use of these inhibitors in either sulfuric or phosphoric acids. In one instance Polyethanol RAD-1220 was tested as an inhibitor for mild steel in 70 percent sulfuric acid at 125° C. for 80 minutes. Under these conditions, which admittedly are quite severe, the inhibitor at 0.2 and 0.4 percent concentration was apparently oxidized and rendered ineffective. Also, these materials were tested by a laboratory in the steel industry as inhibitors for pickling operations. In 10 percent sulfuric acid it was found that inhibition was obtained, but the inhibitor was not particularly stable and had to be replenished frequently to maintain the desired effectiveness.

Similarly, phosphoric acid has been tested only in a very preliminary manner. Polyethanol RAD-0500, 0515 and 3115 were tried as inhibitors for mild steel at 0.2 percent concentration in 40 and 85 percent phosphoric acid at 80° C. The inhibitors were not decomposed in this case, but excessive foaming occurred and the tests were discontinued. It is expected that a more complete investigation of these acids at reduced concentrations and temperatures will be carried out at some future date.

The results obtained by Mr. Brown are interesting in that they confirm the effectiveness of this type of inhibitor in 10 percent hydrochloric acid over a temperature range of 75° C. up to the boiling point of the acid. The application of boiling 10 percent hydrochloric acid for practical industrial cleaning appears to be a desirable modification of the general procedure now used.

Questions by Charles M. Blair, Tretolite Company, Webster Groves, Mo.:

Were the inhibited acid solutions agitated during the corrosion test period?

Was the reproducibility of test results satisfactory, or was there considerable variation in rates of attack between solutions containing the same concentration and kind of inhibitor?

Authors' Reply:

No agitation was provided in these tests. Agitation was ommitted so that as many variables as possible could be eliminated in the interest of reproducibility of the testing conditions.

In regard to reproducibility of results, it was found that where the inhibitor was particularly effective, i.e., corrosion rates of about 0.20-inch per year or less being obtained, duplicate determinations varied within 1 to 4 percent of each other. As the corrosion rate increased to 0.30 IPY or more it was observed that the results were not always so consistent as noted above. In a few instances differences of 10 to 20 percent were obtained.

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Current Requirements for the Cathodic Protection of Steel in Dilute Aqueous Solutions. By G. R. Kehn and E. J. Wilhelm. *Corrosion*, 7, No. 5, 156-160 (1951) May.

Discussion by S. C. Britton, Tin Research Institute, Greenford, Middlesex, England:

In your May issue, Kehn and Wilhelm presented the results of an examination of the method of determining protective current density to which my name has become attached. I was glad to see this for although I did not agree with all that the authors had to say, I feel sure that they are quite right to conclude that caution is necessary in applying the method to practical problems.

It is well to recall that the paper[1] which originally

1. U. R. Evans, L. C. Bannister and S. C. Britton. *Proc. Roy. Soc.*, A, 131, 335 (1931).

described the break in cathode polarization curves at the protective current density was aimed at solving a problem in pure science, concerned with the mechanism of corrosion. The measurements were made in defined conditions, and it was never intended that the results should be applied indiscriminately to all conditions. It was pointed out that, even for the conditions studied, iron was to some extent exceptional in that slow movements of potential, due to absorption of oxygen by ferrous compounds, could affect the shape of the polarization curve. It would thus be expected that the protective current density determined by the method for iron and steel would depend very much on the conditions of experiment and the interpretation of the curves obtained.

It is well appreciated that laboratory measurements of the speed of corrosion must be applied with great care to practical problems. It is equally necessary that laboratory measurements of other corrosion phenomena should be applied with due regard to possible differences between experimental and practical conditions. Neglect of this may make such measurements suspected when their practical application appears to fail. No suspicion was of course cast by Kehn and Wilhelm on the original results or on the conclusions drawn from them, but unless the position is understood, less careful authors, and readers, may be led to a wrong conclusion.

•

Dicyclohexylammonium Nitrite, A Volatile Inhibitor for Corrosion Preventive Packaging. By A. Wachter, T. Skei and N. Stillman. *Corrosion*, 7, No. 9, 284-294 (1951) Sept.

Question by Louis M. Nieliwocki, Sabine River Works, E. I. DuPont de Nemours & Co., Orange, Texas:

Do the heavier grades of VI papers offer more protection in packaging than the lighter grades?

Authors' Reply:

Laboratory experiments and field experience indicate that the duration of protection by the inhibitor coated paper is approximately directly proportional to the amount of dicyclohexylammonium nitrite per square foot of paper. The usual inhibitor loading on paper for commercial use is about one gram of the amine nitrite per square foot. Depending on the vapor-barrier nature of the carrier paper, this loading is sufficient to provide protection for periods up to several years. For long-term storage greater than five years a two gram loading may be preferable. The degree of protection offered by the heavier loaded paper appears to be no better than that observed with one gram paper; the heavier loading merely lasts for a longer time. The thickness of non-barrier paper does not seem to have any significant effect on performance of the inhibitor. With an inhibitor coated barrier paper some increase in protection and life would be expected as the thickness of the vapor-barrier layer is increased.

Question by James E. Shields, Alox Corp., Niagara Falls, N. Y.:

The question I raised during the discussion of this paper was: What would be the effectiveness of the dicyclohexylammonium nitrite, volatile inhibitor in protecting metal previously coated with uninhibited or inhibited mineral oil against atmospheric corrosion? Since metal parts or assembled metal articles such as ball bearings are usually found covered with an oily film either placed there intentionally for protection during fabrication or the lubricants used during fabrication still remain on the articles prior to packaging, must this oily film be removed in order to obtain the full effectiveness of the volatile inhibitor?

Authors' Reply:

The oily film that may be present on steel parts need not be removed in order to obtain full effectiveness from the volatile corrosion inhibitor. Experiments and actual experience have shown that the inhibitor is compatible with films of protective oils on steel. At those locations on an oiled metal surface where water-vapor or condensed water can get through the oil film, the volatile inhibitor would accompany such water and prevent it from causing corrosion.

Questions by Marc Darrin, Mutual Chemical Co. of America, Baltimore, Md.:

Dr. Wachter has pointed out that dicyclohexylammonium nitrite is not a panacea, but the properties he has described suggests some interesting possibilities. Could this inhibitor be used in an anti-tarnish paper for silver? Has it been tried for prevention of corrosion in steam condensate lines? Could it replace slushing compounds for temporary protection of machined parts? What is its compatibility with other inhibitors? For instance, could chromate be used in an aqueous phase while the volatile nitrite protects in the vapor phase?

Authors' Reply:

This inhibitor does not appear to be useful as an anti-tarnish paper for silver.

It has not to our knowledge been tried for prevention of corrosion in steam-condensate lines. It does not seem that it would be successful in such applications since it probably would be destroyed too rapidly by the high temperatures in boilers and its cost would be too high.

An important industrial application for the inhibitor is as replacement for slushing compounds to obtain temporary protection of machined parts that must be stored before assembly into finished articles. This is accomplished by lining bins or containers with the inhibitor paper. The chief advantage of this procedure is avoidance of the necessity for degreasing the parts in order to assemble the finished article.

Although direct data are not available, it would be expected that this amine nitrite would be compatible with most water corrosion inhibitors. Since the amine nitrite is an excellent inhibitor in water for steel, if the amine nitrite is used in the vapor space above the water it would be reasonable also to use it in the water. This procedure would be desirable in order to help maintain the inhibitor in the vapor space.

Cathodic Protection of An Active Ship in Sea Water —Part II. By K. N. Barnard. *Corrosion*, 7, No. 4, 114-117 (1951) April.

Discussion by E. C. Reichard, American Smelting and Refining Co., Research Dept., Barber, N. J.:

Mr. K. N. Barnard and his associate are to be commended for the excellent work that they have done and are continuing to do. This work of applying cathodic protection to active ships in sea water is especially noteworthy. Mr. Barnard has succeeded in reducing masses of confusing theory into practical field tests. These tests have been conducted on a plane that indicates the usefulness of cathodic protection for commercial shipboard application.

The writer has no intention of detracting from the work that has been reported. Further information might be of interest, however, concerning the preferential attack of the magnesium anodes in the vicinity of the copper core. This has been attributed to the presence of a copper impurity in the anode metal; copper that was dissolved from the core during casting of the anode. This reasoning is pointed out in the legend for Figure 9 and Mr. Barnard's accompanying discussion. Mr. Barnard also implies that use of a steel instead of a copper core would avoid the preferential attack of the anode metal in the core vicinity.

It is believed that further information should be given at this time concerning the effect of copper on the performance of magnesium anodes. Magnesium anodes used in this country are generally cast in metal molds. The use of metal molds results in relatively rapid cooling of the anode castings. Under these circumstances of rapid cooling the amount of copper that could be dissolved from a copper core is limited. In addition, the copper that might be dissolved would tend to remain in solid solution during cooling of the metal as a result of the greater solubility of copper in magnesium that is rapidly cooled. Up to 0.5 percent copper can be retained in solid solution with metal that is rapidly cooled. With the copper in solid solution, little difficulty would be encountered with the type of preferential attack mentioned by Mr. Barnard. This is because the potential of the metal with copper in solid solution would be slightly more cathodic than that of the more anodic low copper region. The only difficulty to be encountered with these anodes would be as the core became exposed. Then intensive attack of the magnesium metal in the core vicinity would result because of the intense local action from the close coupling of a bare copper rod and magnesium metal.

Evidently the anodes in question were not cast in metal molds. Otherwise little of the difficulty mentioned by Mr. Barnard would have been encountered. It is interesting to note that if the anodes were cast in sand, then slower cooling would result. With slow cooling the magnesium would have been molten for greater periods of time and as a result greater quantities of copper would be dissolved from the core. It so happens that the metallurgy of magnesium is such that the capacity for magnesium to hold copper in solid solution when it is slowly cooled is greatly reduced; instead of 0.5 percent, 0.2 percent is the range of copper solubility in slowly cooled magnesium metal. Because of this fact, the copper dissolved in molten magnesium would, under slow cooling be precipitated in the form of a Mg_2Cu compound. This compound would be formed at the grain boundaries of the magnesium metal. Under these circumstances the resulting structure of the anode metal would consist of Mg_2Cu particles in a magnesium matrix. This type of structure would corrode very rapidly because of the intense local action that results from local anodes of magnesium and many local cathodes of Mg_2Cu compound. It is believed that this is the type of structure that was responsible for the severe attack of the magnesium in the vicinity of the core as pointed out by Mr. Barnard.

This type of attack could be avoided by rapid cooling of the magnesium castings through the use of metal molds or chill plates in the core vicinity. Another attack on this problem as mentioned by Mr. Barnard is the use of steel core in order to bypass this entire copper problem.

It might be interesting to note at this point that extensive tests are in progress and are being reported through the Galvanic Anode Committee of this society* on the effect of copper when distributed throughout the entire anode section. In these tests it has been found that copper contents as high as 0.5 percent can be tolerated in magnesium anodes used in soil work without any significant reduction in current output or current efficiencies. This work has been further confirmed by extensive tests undertaken by this laboratory which have been conducted with anodes performing in sea water. In either case, copper contents as high as 0.5 percent have not been found to cause any significant reduction in current output or efficiencies of magnesium anodes. These favorable results have been possible because the copper, in each case, has been retained in solid solution as a result of established manufacturing practice favoring rapid cooling of the anode castings.

It is hoped that Mr. Barnard will be able to furnish more information concerning the anodes used in his work and recent developments that have been made. In addition, information concerning the anode to hull area relationships would be of interest.

In closing, I would like to repeat that Mr. Barnard is rendering a very worthwhile service with his work and has made a significant contribution concerning the use of cathodic protection methods.

* National Association of Corrosion Engineers' Technical Practices Committee 2.

Reply by K. N. Barnard:

The difficulty encountered using copper rods in the anodes has been eliminated here by the use of steel conducting rods.

The explanation given by Mr. Reichard of the relatively poor performance of "New Liskeard's" magnesium alloy adones in the vicinity of the copper rods, cast in the anodes, seems to be reasonable. In a later casting two copper rods were cast into 12-inch wide anodes against a steel drag which quickly

cooled the magnesium in way of the copper rods. These anodes behaved normally and no preferential attack was observed near the rods. In this case an analysis of the anodes near the copper rods showed that very little copper had dissolved from the rods.

A note by Dr. G. L. Christie of this Establishment follows in which the results of the analysis and a more detailed description of the anode appearance is given.

Comments by P. M. Aitken and G. L. Christie, Defense Research Board, Naval Research Establishment, Halifax, Nova Scotia:

Note on the Behavior of Magnesium Anodes Cast on Copper Cores

Two patterns of magnesium anodes that had been used in the cathodic protection trials on active ships, and had behaved very differently in service, were examined to determine, if possible, the cause of the different behaviors. At the time this investigation was made none of the original anodes were available so chemical analysis and metallographic examination were made on the best preserved specimens of used anodes.

Type I Anode. These anodes were originally seven inches wide, three inches deep and sixty inches long. They were cast in an all-sand mold. A single copper rod 5/16-inch diameter running the full length of the anode was used as an electrical conductor. The contour of the used anode sectioned for this investigation is shown in Figure 1a. Figure 1b shows the more typical contour of the used anodes of this set. Figure 1c gives the location of the analytical samples and metallographic specimens. The anode in Figure 1b was mounted in a holder that protected the base from contact with the sea water. This type of holder was not used with the anode of 1a, which accounts for the difference in contour at the base of the two sections.

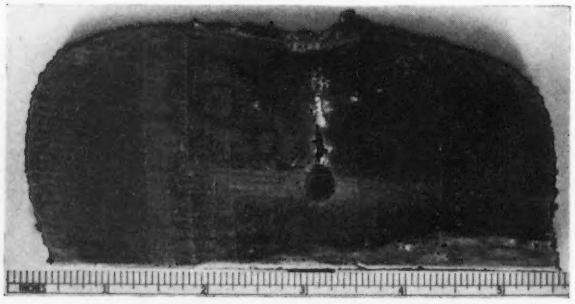


Figure 1a

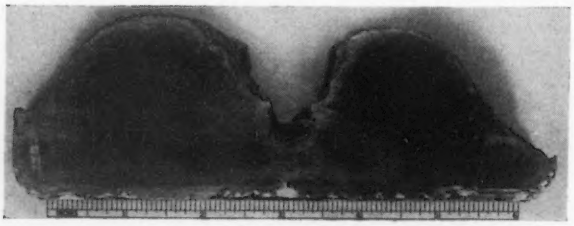


Figure 1b

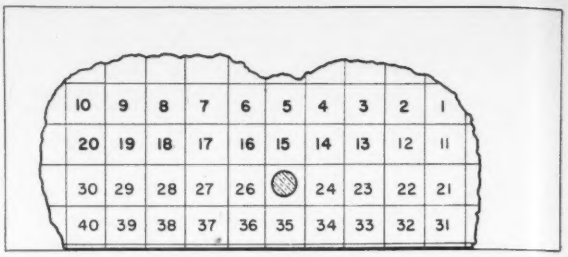


Figure 1c

Type II Anode. These anodes were originally twelve inches wide, three inches deep and sixty inches long. They were cast in a mold with a cast iron drag and sand cope. Two copper rods 5/16-inch in diameter were used as electrical conductors in these anodes, and in the casting operation these conductors were on the drag side of the mold. The contour of the used anode in this investigation, which is not typical of those removed from this ship, is shown in Figure 2a. The anode sectioned for this investigation was not connected to the ship over part of the time the ship was in the water, and consequently was not

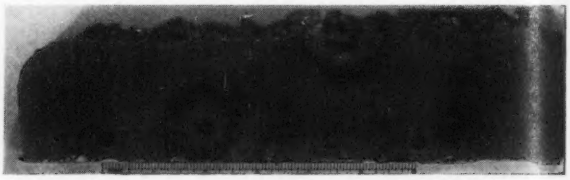


Figure 2a

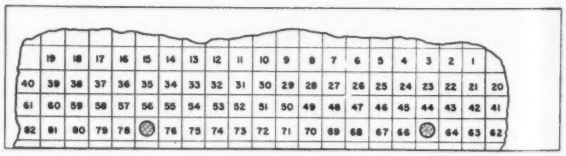


Figure 2b

consumed as much as the anodes that had supplied current over the full duration of the test. Figure 2b shows the location of the analytical samples and metallographic specimens.

Metallographic Examination

a) Macro. The Type I anode contained a very prominent casting pipe just above the copper conductor. This pipe was absent in the Type II anode.

b) Micro. Specimens 4, 5, 9, 22, 26 and 35 of Type I anode and 5, 25, 46 and 76 of the Type II anode were polished for metallographic examination. In all positions the alloy showed the two phase structure normal for this alloy in the "as cast" condition. In both anodes microporosity was evident. Pores, however, were more numerous in the Type I anode. This condition was substantiated by the lower density of the Type I anodes; 1.812 as compared with 1.821 for the Type II.

Chemical Examination

Chemical analyses for copper were made on drillings taken from the numbered locations shown in

Figures 1c and 2b. Copper analyses were made colorimetrically by extraction with carbon tetrachloride of the yellow complex formed with sodium diethyldithiocarbamate. The following results were obtained.

TABLE I

TYPE I ANODE		TYPE II ANODE	
Sample No.	Copper Percent	Sample No.	Copper Percent
4	0.11	3	.003
6	0.19	9	.006
13	0.010	15	.009
15	0.59	22	.006
17	0.010	24	.005
22	0.010	34	.002
24	0.11	36	.003
26	0.16	42	.002
28	0.011	44	.002
31	0.011	46	.004
33	0.011	56	.005
35	0.011	62	.008
37	0.012	64	.003
39	0.012	66	.007
		68	.007
		70	.004
		72	.007
		76	.063
		78	.003

The low copper values shown for the Type II anode are of the same order as those found in uncontaminated metal. An anode from the same supplier but which had been cast on an iron core was analyzed and found to contain 0.002 percent copper.

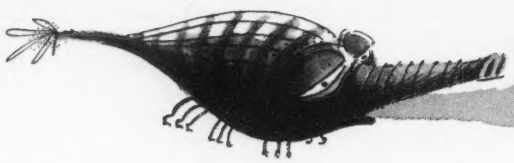
It is apparent from these results that in the Type I anode, copper has been dissolved from the center conductor giving a copper rich region which approximated very closely the contour that the anode assumed in service.

Part of this excessively rapid wastage may be attributed to the micro porosity of the casting, but specimen Number 9 in the low copper region was not visibly less porous than was Number 4 in the area that wasted rapidly. The Type II anode showed little copper in solution and no areas of accelerated attack in spite of the fact it showed some microporosity.

In these anodes it would appear that the differential in copper content in the Type I anode lead to an accelerated wastage of that anode. Since the anode used for examination had behaved in a manner different from the majority used in the test on the ship, it is possible that the copper content was not as high as in those where the wastage was more severe. A higher copper content could form a copper rich phase which, as pointed out by Mr. Reichard, could give rise to the observed accelerated attack since the anodes were not heat treated prior to use. In any case, no copper rich phase was visible in the grain boundaries of any of the polished specimens. In the Type II anode solution of the copper had been almost prevented by using a foundry method that produced a more rapid solidification of the casting.

Corrosive fumes...

Salt air...



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Moist air...

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Topic of the Month

A Corrosion-Inhibitive Coating for Buried Lead-Covered Cables*

By WILEY D. SANDERSON*

Method of installing inhibited coating on cable with clay tile covers.

POWER AND communication cables are normally carried in an underground duct system of fiber or clay tile. Jute- and steel-armored cable often serves in marshy places and across streams, roadways, etc. Recently, however, there has been an increasing tendency to bury isolated, individual cable lines which cannot be economically installed in ducts or on which the intended length of required service is unpredictable.

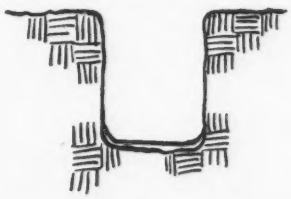
Buried cable must be protected against corrosion, to exclude particles of soil from contact with the sheath. This, if allowed, would set up oxygen-concentration cells which would exclude oxygen from certain areas while allowing it access to other adjacent areas, thereby producing an interchange of current and causing corrosion. Likewise, exposure of the sheath to various types of soil, variations in its moisture content, or to different concentrations of chemically-active substances will produce damage. The installation of metallic structures through soils of high and of low resistivity is conducive to corrosion at the latter locations. And, of course, exposure to cinders or acetic acid is highly dangerous.

Clay-Base Emulsion Used

In order to provide protection for buried, lead-covered cables, an asphalt coating has been utilized on The Detroit Edison System. For ease of application, the asphalt has been employed in an emulsified state. Both a clay-base type and a soap-base type were investigated, but the clay type proved cheaper and was just as satisfactory.

The theory for the prevention of corrosion on cables involves in addition the production of a passive film on the lead sheath, or of an insoluble outer surface. Various chemical inhibitors may be utilized. Those of importance are: silicates, chromates, phosphates and to a certain extent sulfates and carbonates. Silicates, in general, form an insoluble lead-silicate layer on the outer surface of the lead sheath. The action of chromates is not so clearly defined, but their action is presumably that of producing either an insoluble lead-chromate film or a protective oxide film on the surface of the lead. Both actions take place, especially

Where the bottom of the cable trench is especially soft or wet, it should be covered with tar paper.



The cable should be supported on blocks at least four inches above the bottom of the trench. The asphalt is to be smeared all around the cable sheath (lifted from blocks) by hand approximately 1/16-inch thick. Gloves should be worn. The sheath should be reasonably free of dirt. It is not necessary to wash grease from the sheath because the asphalt emulsion will mix with grease.

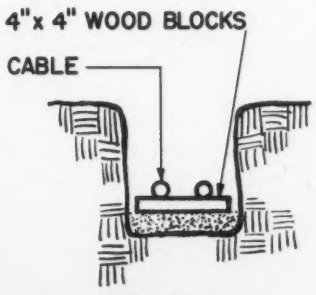
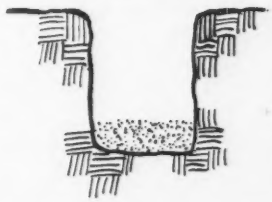
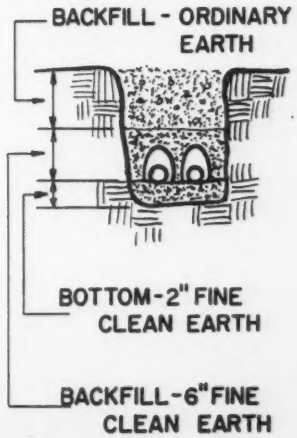


Figure 1

If the bottom of the cable trench contains cinders or sharp stones or other material which might be injurious to the cable sheath, sifted or other fine earth should be placed on the bottom of the trench. (Approximately two inches deep.)



As the asphalt dries, its color turns from brown to black in about an hour. The supporting blocks may be removed then and the cable lowered to final position. After the tile covers are installed the trench may be backfilled. If backfill earth contains injurious material, fine clean earth should be used for the first six inches of backfill.



* Based on a paper presented before the Transmission and Distribution Committee, Edison Electric Institute, Chicago, May 6, 1940.

* Supervising Engineer, Cable Corrosion and Loading, The Detroit Edison Co., Detroit, Mich.

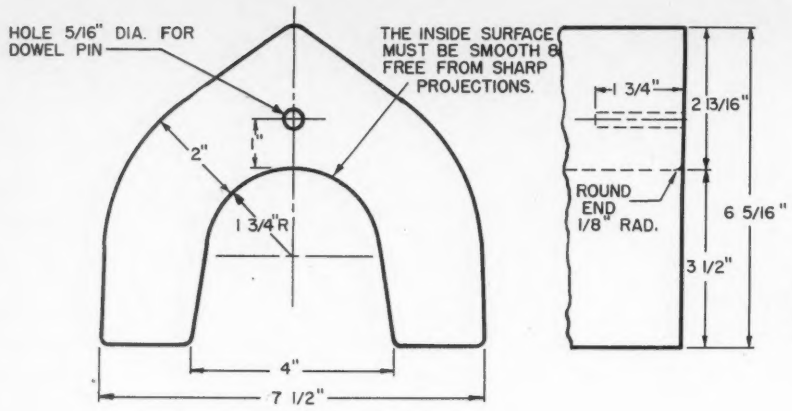


Figure 2—Tile clay should be burned to a hardness providing a crushing strength of not less than 5000 lb. per sq. in., and with 10 percent or less absorption. (Note: In original design two bearing surfaces were tapered.)

in alkaline surroundings such as are normally encountered in Detroit.

Inhibitors Are Added

In addition, therefore, to the mechanical protection provided by the asphalt coat on the cable sheath, a second line of defense has been provided through the addition of one percent, each, by volume, of sodium silicate and sodium dichromate. Too much silicate causes the asphalt to blister and too much dichromate tends to bleed and pit the coating. The material can be prepared by mixing together one-quart of 40 percent sodium silicate and a neutralized solution containing one-half pound of sodium dichromate in ten gallons of emulsified asphalt. The neutralized solution of sodium dichromate referred to is prepared by dissolving the dichromate crystals in only enough water to give a saturated solution, then converting it to a neutral sodium-chromate solution through the addition of sodium hydroxide. The dichromate solution has a red color which turns to the characteristic yellow of sodium chromate as the solution is neutralized. Since the use of the acid dichromate without its neutralization to a chromate would both precipitate the asphalt emulsion and cause the silicate to gel, it is very important that instruction be carefully followed.

It has been proved that about one one-thousandth percent of solution of silicate or one-half percent of chromate is sufficient to protect a lead sheath against corrosive action. Furthermore, tests indicate a combination of the two chemicals is more efficacious than either one alone. An excess of chemical is provided in order that the small amount necessary will gradually seep out of the coating and provide a protective film over a long period.

Because this cable-coating material need be used the year around, sufficient denatured alcohol (approximately 5 percent) is added during its preparation to prohibit freezing to as low as zero, Fahrenheit. This is 14 degrees F. lower than minimum allowable installation temperature of paper and lead cable. Otherwise, the material will not function properly at a temperature lower than 45 F. The compound is of a dark-brown color, with the consistency of thick cream and dries, dependent upon humidity and rate of circulation of the air, in one hour or less. Since its eventual state is that of a semi-plastic coating, there is no chipping nor cracking of the surface as is often the case with enamels. This cable-coating material is now commercially available in one-gallon and five-gallon containers.

Material Used on Steel Tanks

The use of this material has recently also been extended to the corrosion protection of buried steel tanks.

A copy of the illustrated instructions for installation is reproduced herein and is self-explanatory. (See Figue 1.) It may be noted that application is to be made with rubber gloves. Although no detrimental effect was anticipated from any of the ingredients in contact with the bare hands, the use of gloves was adopted upon the advice of our medical staff. For best results, the gloves should be thin, smooth surfaced and fairly pliable.

In order to make sure protection is given buried cables against careless or unauthorized excavators, a heavy, gothic-style, clay-tile cable cover is installed over each cable. Dowel pins are inserted in holes in the tile to hold them in line. A drawing covering the construction of the cable cover is included. (See Figure 2.) A similar, correspondingly larger cable cover is used to protect the joints involved.

Incidentally, the protection afforded the cable by the tile covers may be more than mechanical. The silt percolates through the interstices between the tiles is necessarily very finely divided in character and would undoubtedly approximate the type of colloidal soil which is known to be protective to underground metallic structures with which it comes in contact.

Cost Is Moderate

The cost of this method of protection of buried cable is quite moderate. The approximate expense per foot of 350-M-cir-mil, three-conductor, 24-kv cable, (2⅝-in. outside diameter) chargeable to corrosion protection, is indicated in Table I. The soil encountered at Detroit is usually clay, sand, or loam, with comparatively few obstructions.

TABLE I

Materials	$0.21
Labor	0.27
	$0.48

The first installation of a cable protected with this cable-coating compound was made in 1939. Laboratory and weathering tests, however, were carried on for some time previously. A considerable mileage of cable has now been installed according to this, a standard method with the Detroit Edison Company, and to date no corrosion fault has occurred. Inspections indicate no physical change in the coating and good adherence to the lead.

The idea of using the indicated chemicals to provide protection for lead cable sheaths is not new in principle. It is the method of application, only, that merits attention. There seems to be but one element seriously detrimental to the formation of a chemically passive film on the lead. This is a chloride. However, in their presence the excess of chemicals employed is still effective. Fortunately, little sodium chloride used for thawing street ice reaches buried cable.

It cannot be accurately predicted at present what will be the life of a cable protected by this coating. From the standpoint of cost, ease of application and apparent protective effect, however, this material seems entirely satisfactory.

References

1. R. M. Burns, Bell System Technical Journal, January, 1936.

NACE News

Formation of Boston Section Soon Is Forecast

Sam Tour, W.E. Pratt Discuss Corrosion Testing At November Metropolitan Section Meeting

Corrosion News Deadline: 10th of Month PRECEDING Date of Issue

Silica Gel as Dessicant Is Topic at Baltimore

S. S. Hubard, manager of research for Davison Chemical Corp. addressed members of Baltimore Section October 2 on "Prevention of Corrosion of Packaged Materials by Use of Silica Gel as a Dessicant." This talk was a logical sequel to the talk by H. R. Baker on vapor phase inhibitors.

This first meeting of Baltimore Section's year was a dinner meeting at Park Plaza Hotel, Baltimore.

Goodrich Laboratory Tour Featured at Cleveland

Cleveland Section scheduled an inspection trip of the B. F. Goodrich research Laboratory at Brecksville, Ohio for its October 16 meeting. A talk by E. B. Newton, director of Goodrich technical service research entitled "Organic Adhesives as Engineering Materials," also was given.

The November 20 meeting of the section will be held at Cleveland Engineering Society when H. O. Teeple of International Nickel Co., Inc. New York will talk on "Metals for High Temperature Service."

G. H. McIntyre of Ferro-Enamel Corp. will speak January 15 on "Enamel Coatings," at a meeting also to be held at Cleveland Engineering Society.

No meeting will be held during December.

Williamson Resigns

Merritt A. Williamson, Pullman Standard Car Manufacturing Co., Hammond, Indiana, has resigned as chairman of Technical Practices Committee 15—Corrosion Control in the Transportation Industries. He will continue to edit and issue the railroad Corrosion Newsletter.

"Accelerated Corrosion Testing Methods," is the topic of a scheduled address by Sam Tour of Sam Tour, Inc. before the Metropolitan New York Section November 7 at Building Trades Employers' Association, 2 Park Ave., New York. W. E. Pratt of Worthington Pump & Machinery Corp., Harrison, N. J. will be co-speaker. Mr. Tour's remarks are to cover non-standard methods of testing, such as alternate condensation atmospheric corrosion testing, combined wear and corrosion testing and corrosion testing of coatings on metal and agitated aerated sea water testing. Mr. Pratt will discuss high velocity corrosion testing methods and will present data on results of field testing for galvanic corrosion.

The nominating committee is scheduled to report at this meeting.

At the September 26 meeting, held at the same place, Robert R. Pierce of Pennsylvania Salt Manufacturing Co., Philadelphia spoke on "Design of Brick Lined Tanks for Corrosive Service." The subject of this talk was different from others heard by the section so far. Information was given by Mr. Pierce on brick linings, various kinds of cements, impervious lead lining and the outer steel jacket. These materials are necessary to hold corrosives at high temperatures.

His talk was illustrated with slides and two motion pictures showing installation of liners in digester tanks in Germany were shown.

Basin-Ozark Pipe Line Film Is Seen at Chicago Section Meeting

A color motion picture on the construction of Shell Pipe Line Company's Basin-Ozark pipe line was a principal feature of the September 18 dinner meeting of Chicago Section at Chicago Engineers Club. Discussion of corrosion aspects of construction practices followed a short business meeting held with F. M. Watkins, section chairman, presiding.

The evening began with a fellowship hour with R. G. Roberts of Barrett Division of Allied Chemical and Due Corp. as host assisted by Mssrs. Cowart and Romine. The excellent dinner was arranged for by Vic Kalhague.

Substantial interest in formation of a section of the National Association of Corrosion Engineers has been found in the Boston area and a committee of members of the association in the area is submitting a formal application for recognition soon, W. F. Fair, Jr. reported early in October. Dr. Fair was named by H. L. Hamilton, chairman of North East Region to investigate the feasibility of forming a new section at Boston.

The committee conducting the canvass of membership in the Boston area was as follows: H. H. Uhlig, chairman; Massachusetts Institute of Technology, Cambridge, Mass.; John Swift, Lever Bros., Cambridge, Mass.; and E. J. Titsworth, Koppers Co., Inc., Boston, Mass.

Action on the proposal to recognize a Boston Section is scheduled to be taken by North East Region Trustees at their next meeting.

Fontana Addresses East Wisconsin Section

Eastern Wisconsin Section heard Mars G. Fontana, Ohio State University speak on "Corrosion and its Prevention," at City Club, Milwaukee, Wis. October 1. The dinner meeting was attended by about 55. This was the first official meeting of the section and it was marked by decided interest in Dr. Fontana's remarks.

C. P. Larrabee of Carnegie-Illinois Steel Company is scheduled to address the November 5 meeting of the section.

Sabine-Neches Section Hears Talk by Fontana

"Corrosion in the Chemical Industry," was the topic of a talk by Mars G. Fontana of Ohio State University at a meeting of Sabine-Neches Section September 19 at Lake Charles, La. About 40 members and 37 guests were present.

A very active discussion followed Dr. Fontana's remarks.

At a business meeting the following committee chairmen were named: Richard R. L. Ward, Cit-Con Oil Corp., Lake Charles, La., membership; W. F. Oxford, Sun Oil Co., Beaumont, Texas, social and hospitality; C. E. Huddleston, Jr., Socony-Vacuum Products Co., Beaumont, Texas, arrangements and publicity; Lewis M. Nieliwocki, E. I. du Pont de Nemours & Co., Orange, Texas, program.

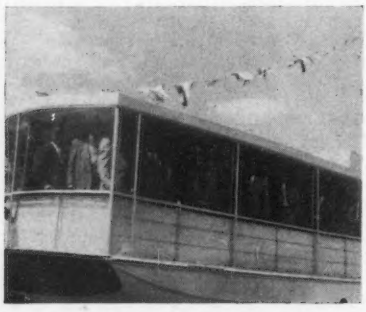
The October 31 meeting at Holland Hotel, Orange, Texas will be devoted to water treatment. The meeting begins at 7:30 p.m.

Detroit Section Sees Need for Aggressive Attack on Corrosion

Corrosion by Acids Is Emphasized in Talk At Houston Section

Emphasis was placed on materials resistant to hydrofluoric and sulfuric acids by Dr. Mars G. Fontana in his address September 18 before 134 members and guests of Houston section. Dr. Fontana is NACE vice-president and chairman of TP-5 Corrosion Problems Involved in Processing and Handling Chemicals. A fellowship hour, sponsored by The Duriron Company, preceded the dinner meeting.

A group of Houston Section members and association officers met Dr. Fontana's plane at the airport and the



Mars G. Fontana, NACE vice-president, is sixth from the left in the group shown here at luncheon "aboard" the North Wind Restaurant, a converted yacht high and dry off South Main Street near Houston. The group comprised the welcoming committee who met Dr. Fontana at the airport. (Wayne Broyles Photo.)

television news program "Houston Today" carried the ceremony on its evening broadcast, which was viewed by those attending the meeting.

Dr. Fontana discussed the types of corrosion experienced in handling chemicals. Slides presented showed corroded equipment, laboratory corrosion test apparatus and curves of corrosion data useful in evaluating corrosion rates and resistance of materials.

The dinner meeting was held at Kelly's Dining Room, Houston.

Allen Heads Committee At Instrument Meeting

A committee headed by E. R. Allen from Houston Section manned the NACE booth at the September meeting at Houston of the Sixth National Instrument Conference. Many instrument engineers stopped to inquire about the association's activities. Committee members were MacGregor Parr, E. P. Doremus, Dick Bender, Perry Spafford, M. E. Holmberg, J. A. Caldwell, E. W. Wallace, Charles Scamman and Jack Battle.

The corrosion session held during the meeting under auspices of NACE featured papers on corrosion by M. E. Parker, consulting engineer and M. A. Judah, engineer on Central Office staff.

Eugene V. Ivanso, salesmanager of nickel alloy sales for Steel Sales Corp. of Michigan addressed 15 members and 7 guests of Detroit Section September 20 at The Engineering Society of Detroit's Rackham Memorial Building, Detroit. This was the first fall meeting of the section. Mr. Ivanso's topic was "Substitution of Metals for Corrosion Resistance."

New officers of the section were introduced as follows: Jack H. LoPrete, Spray Coat Engineering Co., chairman; Leon D. Cook, Wyandotte Chemical Co., vice-chairman; Proctor G. Coates, Michigan Bell Telephone Co., secretary; Walter Cavanagh, Parker Rust Proofing Co., treasurer.

Energetic Attack Needed

It was the concensus of those present there is urgent need for an energetic attack on corrosion problems in the Detroit area, especially in the automotive and allied industrial fields. Appreciation of the advantages of member participation in engineering studies and programs of NACE should be aimed at in these industries. Detroit Section officers made an appeal to NACE members in other sections who have close personal acquaintance with engineers employed in driving distance of Detroit to give their assistance in securing additional members for the section. Likely prospects should be called to the attention of any of the section officers or of the publicity committee chairman, James W. Dunn, United Chromium Co., 1700 East Nine Mile Road, Ferndale, Mich.

Tentative boundaries of Detroit Section have been reported to the Executive Secretary A. B. Campbell as including Port Huron, Flint, and Lansing on the north and the Ohio State line on the south. This recognizes the desire of a group of NACE members located in and near Midland, Saginaw and Bay City to establish a new section in that part of the state. Members located in the western side of the state will be canvassed soon to determine whether or not they will plan to actively participate in the meetings of Detroit Section.

A few Canadian firms and engineers are located where their only practical contact with an NACE section is at Detroit, and the section welcomes any information that will assist in compiling a list of prospects actively interested in corrosion work in Canada.

Regular Meetings Planned

Regular meetings are planned for third Thursdays every other month at 8 pm. Meetings are scheduled for November 15, January 17, March 13 and May 15. All will be held at the Engineering Society's Rockham Building located on Farnsworth Street and Woodward Ave. in Detroit.

Benjamin Linsky, Detroit City Chief Smoke Inspector, will be principal speaker at the November meeting on "An Engineer in Public Service Looks at Corrosion." Tentative plans have been made to hold a combined meeting with The Electrochemical Society in March.

Engineering Approach Recommended

Mr. Ivanso developed a recommended engineering approach to the present erratic metal supply situation after first reminding his audience there is always a best metal for each environment and therefore in most cases there is a second, third best and so on. He pointed out that the availability of certain metals was surprisingly good in small quantities or in a limited number of sizes and shapes.

In a number of instances slow public acceptance of products manufactured from newer types of alloys and clads has resulted in a relatively good supply of practical substitutes for older metals now needed in large quantities for military purposes.

He warned that many engineers, as does the public, frequently think of a substitute as being necessarily downgraded from the quality of the original product. Each substitution should be carefully studied to determine which compromise between cost, availability and suitability for a particular environment will result in the most satisfactory solution. He described several recent situations involving actual upgrading of products with moderate increases in cost and more equitable use of the limited supply of strategic materials.

Fontana Addresses North Texas Section

North Texas Section heard Dr. Mars Fontana of Ohio State University and vice-president of NACE speak on "New Developments in Corrosion Resistant Alloys," at a dinner meeting September 21 at Fort Worth. The Duriron Company, one of the companies for which Dr. Fontana is consultant, was host to the membership at the fellowship hour.

Corpus Christi Barbecue

Corpus Christi Section's annual barbecue was held September 22 at Humble Flour Bluff Picnic Grounds with about 75 present, including wives and children of members and guests. The gathering was informal and there were no speeches and no business. The excellent barbecue was thoroughly enjoyed.

Short Course Discussed

Instructors at the September corrosion short course given by Shreveport Section conducted a panel discussion of the subjects covered in the course at an October 11 dinner meeting of the Section at Caddo Hotel.

Use of Silicones Is Topic at Philadelphia

"Recent Developments in the Uses of Silicones," was the topic of a talk before Philadelphia Section's dinner meeting October 12. Dr. Rob Roy McGregor, of Mellon Institute, was the speaker.

Dinner and the regular business meeting preceded the speaker and his address was followed by a showing of the teletranscription "Manhattan Spotlight," which was broadcast at New York during the 1951 NACE Conference there.

Mars G. Fontana of Ohio State University, will be guest speaker at Philadelphia Section's December 14 meeting, discussing "Corrosion and Its Prevention."

Merits and Demerits of Pipe Line Inner Linings Are Discussed

Plastic and Concrete Linings and Inhibitors Covered by Panel

Several significant facts concerning inner linings to prevent corrosion of pipe lines in petroleum service were brought out in a panel discussion October 9 at the regular dinner meeting of Houston Section. About 80 members and guests were present to hear a resume by Kenneth Alfred, assistant superintendent of Shell Pipe Line Co., Houston, of his paper previously presented before the American Petroleum Institute Los Angeles meeting recently. Panel members participating in the discussion following were Lyle R. Sheppard of Shell Pipe Line Corp. and H. E. Waldrip of Gulf Oil Corp.

Mr. Sheppard, during his discussion of the problem of inner linings for pipes said recent developments of a coating process involving a solvent dispersed vinyl indicate this process may take the place of older methods discussed by Mr. Alfred. The principal difficulty with the solvent dispersed vinyl had been removal of excess solvent, but this has been solved in large measure by use of suction instead of compression sweeping of the coated lines. The hazard of explosion is greatly reduced with suction evacuation, Mr. Sheppard said.

Inhibitor Use Feasible

Mr. Waldrip told of practices adopted by his company involving the use of two types of inhibitor applied at the well to protect first the production string and equipment. This system involves additions of economically small amounts of an agent which makes possible preferential wetting of tubing surfaces by oil, which, when achieved, effectively prevents attack by salt water and other corrosive agents in the crude. This protection is extended into gathering lines, tanks and pipe lines, and because of the very small quantities necessary to achieve results, is proving economically feasible, he said.

Caustic and chromate treatment of distillate lines by his company was principally a corrosion mitigation measure, but collateral benefits have developed in the improvement of the C factor of the line from 126 to 144 as a result of improved surface smoothness.

Three Systems Discussed

Mr. Alfred's discussion covered three principal methods of inner coating:

1. Plastic coating of the pipe line in the ground.
2. Concrete coating at a coating plant.
3. Concrete coating of the line in the ground.

His discussion was related to experience with these methods in West Texas lines handling the highly corrosive West Texas and New Mexico sour crudes. Principally the lines so treated were gathering lines where load factors were such opportunities existed for separation of salt water from crudes.

General Observations

General observations applying to all three methods made by Mr. Alfred were:

1. Principal trouble was with joints welded after coating, as in all inner lining methods.

2. Inspection of the quality of the coating was unsatisfactory even in yard-lined pipe where mirrors were used. Nipples incorporated into the line were useful but not completely indicative of the quality of the coatings.

3. Lining in place involved difficulties with the "loss" of the cleaning tools and coating plugs in the line, necessitating costly and time consuming searches and clearance.

4. Humidity and temperature are critical in plastic coating because of the need for quick drying.

5. The effects of gravity on the uniformity of the linings are noticeable. In the case of concrete there is a collection of material at the bottom of the line which reduces the capacity.

6. Plastic-lined pipe can be successfully welded over an inserted sleeve at the joint which effectively bonds with adjacent lining, which as far as inspection of test joints showed, provides an effective barrier against attack at the weld. A ⅛-inch asbestos gasket set in sodium silicate paste also shows promise in protecting welded concrete line pipe joints.

7. The practice of cutting hand holes at welded joints in concrete lined pipe through which mortar is applied by hand to the interior of the weld area

(Continued on Page 6)

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Merits and Demerits—

(Continued From Page 5)

leaves a weak point in the pipe where the patches are welded over.

Cleaning Procedure

Cleaning procedure for yard coated pipe is essentially the same no matter what lining is intended. This is also true of lining in place, with the possible excepton slightly greater care must be taken preliminary to plastic coating, it was indicated. Lines used for transportation of corrosive crudes if left 24 hours after cleaning will exude salt and sulfur from the basis metal, it was reported. These are destructive to the bonding of all kinds of linings, and it was recommended a second cleaning of the line follow the first after a delay to permit the corrosives to collect on the inside of the pipe.

Mr. Alfred's remarks on cleaning dealt only with plug pushed wire brushes and steel shavings. Mr. Sheppard said a new cleaning tool which involves air motor driven scrapers operating circumferentially has proved to be a more effective cleaning method. Furthermore, because the tool is controlled by a cable it can be readily located if it gets stuck. The advantages of having both circumferential and longitudinal cleaning are obvious, he said. This tool, if left running in place without forward motion is so effective it will cut its way out of the pipe in time, he said.

The principal disadvantage of coating in place is the impossibility of being sure the coating is continuously good. The possibility of testing coatng continuity by electrical methods was discounted when Mr. Waldrip revealed his company's tests of coupons indicated a very low resistivity.

Mr. Sheppard revealed an experience by his company involving the use of sodium silicate as an inhibitor in a line. Inspection of the cement lined pipe revealed the sodum silicate had penetrated about half the thickness of the lining, filling pores and improving the coating. This line, in service 8 years, has had no leaks. Unlined pipe would be expected to need replacement in the same service in 5 to 7 years.

Concrete Lining Advantages

Advantages of the concrete lining are principally in extension of pipe life, making possible the continued use of lines which otherwise would have to be replaced. Under present supply conditions, this might not always prove feasible, it was pointed out. As far as his experience goes, Mr. Alfred said, the pipe he has seen concrete lined apparently has as good performance characteristics as unlined pipe, if not better. Pressure changes do not seem to affect the lines, being limited only by the strength of the pipe. Improved C factors frequently are experienced. No measures have been taken to prevent pump abrasion by concrete particles, he said.

One trouble frequently encountered in lining pipes with concrete is the slumping of the lining. It sometimes happens that after the lining has been applied it will detach from the walls and fall into the pipe, necessitating a cleaning operation and re-run of the lining. It was suggested this might be avoided by the addition of 2 to 3 percent of hydrated Bentonite which would form a gelatinous bond that might hold the concrete in place until it hardened.

Mr. Alfred's conclusions regarding inner linings were, as far as the conditions experienced with sour crude are concerned:

1. Any lining that will pay out in approximately 20 months is economically desirable.

2. Lined pipes in use in the Permian Basin are still in service after two years.

3. Lining in place has the added advantages of not disturbing the right of way unduly and not affecting pipe exterior coating when present.

A new sleeve lining for pipes has been developed which is designed to be inserted and expanded in place and then cured.

Derk Holsteyn expressed the opinion that linings were not generally feasible for refinery piping.

Chairman Perry P. Spafford announced he would name a nominating committee to propose a new slate of officers to take office after January 1.

Hosts for the fellowship hour preceding the meeting were Anderson Bros. Corp., S. D. Day Company, Dixie Chemical Co., Farley Co., Great Southern Supply Co., Johns-Manville Sales Corp., James E. Mavor Co., Mayes Bros. Inc., Midwestern Engine & Equipment Co., Non-Corrosive Products of Texas, Owens-Corning Fiberglas Corp., Plastic Coating Corp., Rosson-Richards Co., Tube Kote Inc., Standard Pipeprotection, Inc.

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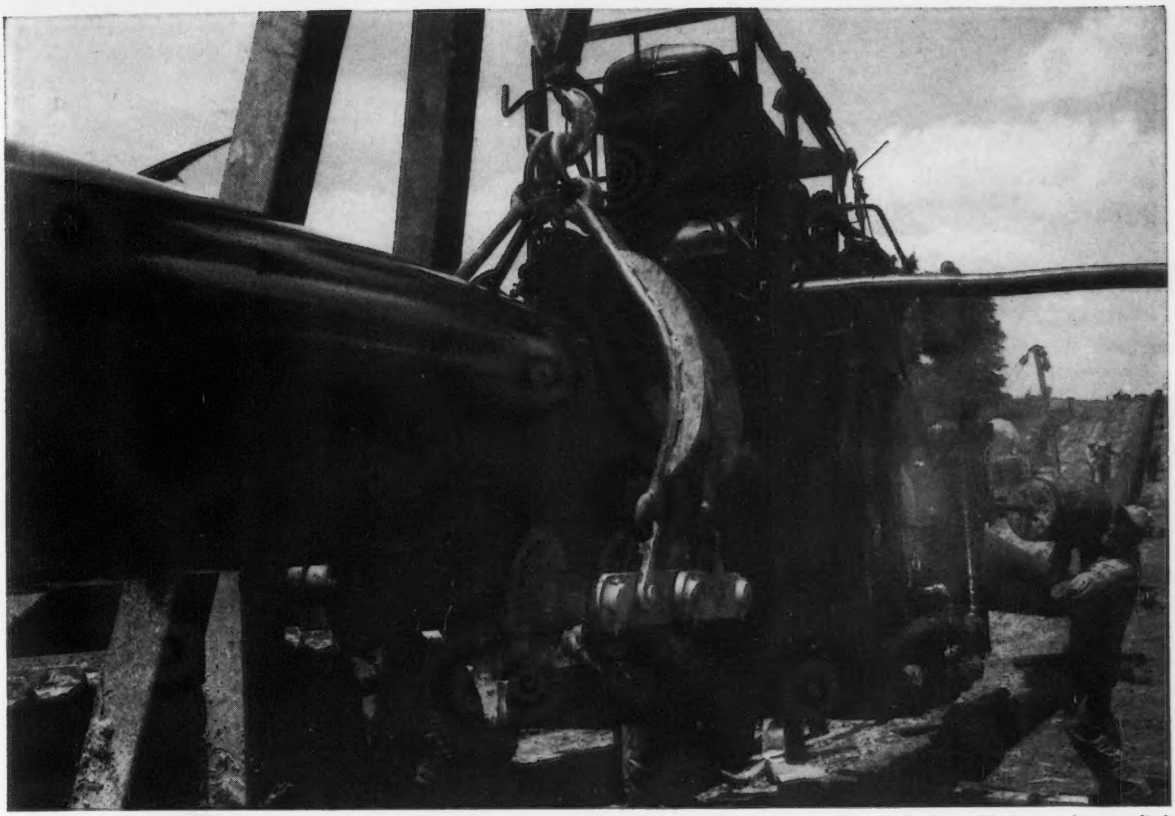

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South Central Region Meeting Registration Is 347

Registration at the South Central Regional meeting at Corpus Christi October 17-19 was 300 men and 47 women. This is the largest registration at a South Central Regional meeting so far, and a rapid-fire program consisting of 12 papers and two discussion sessions that went overtime, held the interest of those attending. A well-rounded program of entertainment was enjoyed, including a visit to King Ranch Saturday where a barbecue was served.

TP-1 and TP-6G held all-day meetings Wednesday; TP-3 held a meeting Wednesday afternoon. Over 80 members and guests attended the TP-1 meeting and a new committee TP-1H on Casing Corrosion was formed under chairmanship of Jack Battle, Humble Oil & Refining Co. to study a problem rapidly becoming one of the most expensive in the industry. Twenty-two TP-1 members came by chartered plane from the Permian Basin Tour.

TP-6G is completing work on its final report on surface preparation of steels which it is planned will be concluded during the 1952 conference.

H. H. Anderson of Shell Pipe Line Company, speaking at the annual luncheon, urged corrosion engineers to diversify their interests and apply themselves more to the job of selling management.

The 1952 regional meeting is scheduled to be held at New Orleans October 22-24.

Nominations for regional officers in 1952 were made as follows: M. C. Fleming, Phillips Petroleum Co., Bartlesville, Okla., chairman; H. E. Waldrip, Gulf Oil Corp., Houston, vice-chairman; Thomas S. Moffatt, Jr., Columbia-Southern Chemical Corp., Corpus Christi, secretary-treasurer. These officers will be voted on by letter ballot.

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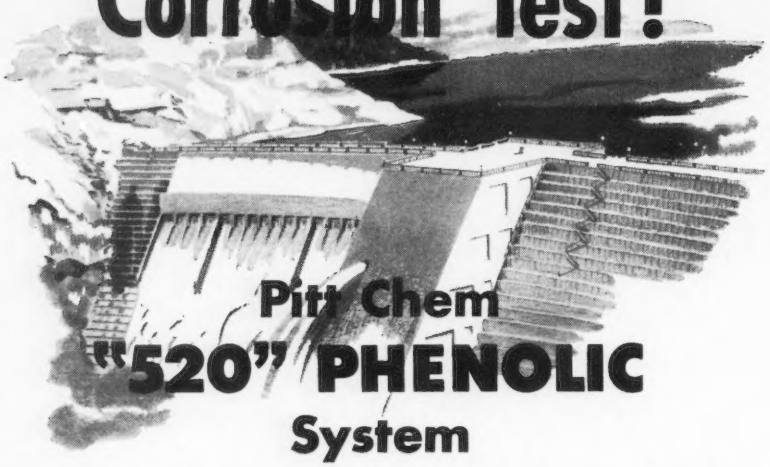

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If *you* have a fresh water corrosion problem, in storage tanks, reservoirs, power dams or water transmission systems, we can help you check corrosion, reduce maintenance costs, and lengthen equipment life. ● *Technical information and engineering assistance are yours for the asking.*

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NACE Participates in ACS Diamond Jubilee

N. E. Berry, president of NACE represented the association at the American Chemical Society Diamond Jubilee celebration in New York on the afternoon of September 5. At an impressive ceremony held in the armory, a large number of domestic technical societies and representatives of about 40 foreign technical societies formally presented greetings to ACS on its 75th anniversary. The occasion was enlivened by the colorful gowns and hoods worn by the representatives.

The felicitations of NACE were phrased in a letter which was presented to Dr. N. Howell Furman, ACS president.

The letter said:

As seems appropriate for one of the youngest of the family of societies represented here on this momentous occasion, the greetings of the National Association of Corrosion Engineers will be both simple and brief. But this does not in any way diminish the sincerity of these felicitations to the American Chemical Society on this your seventy-fifth birthday.

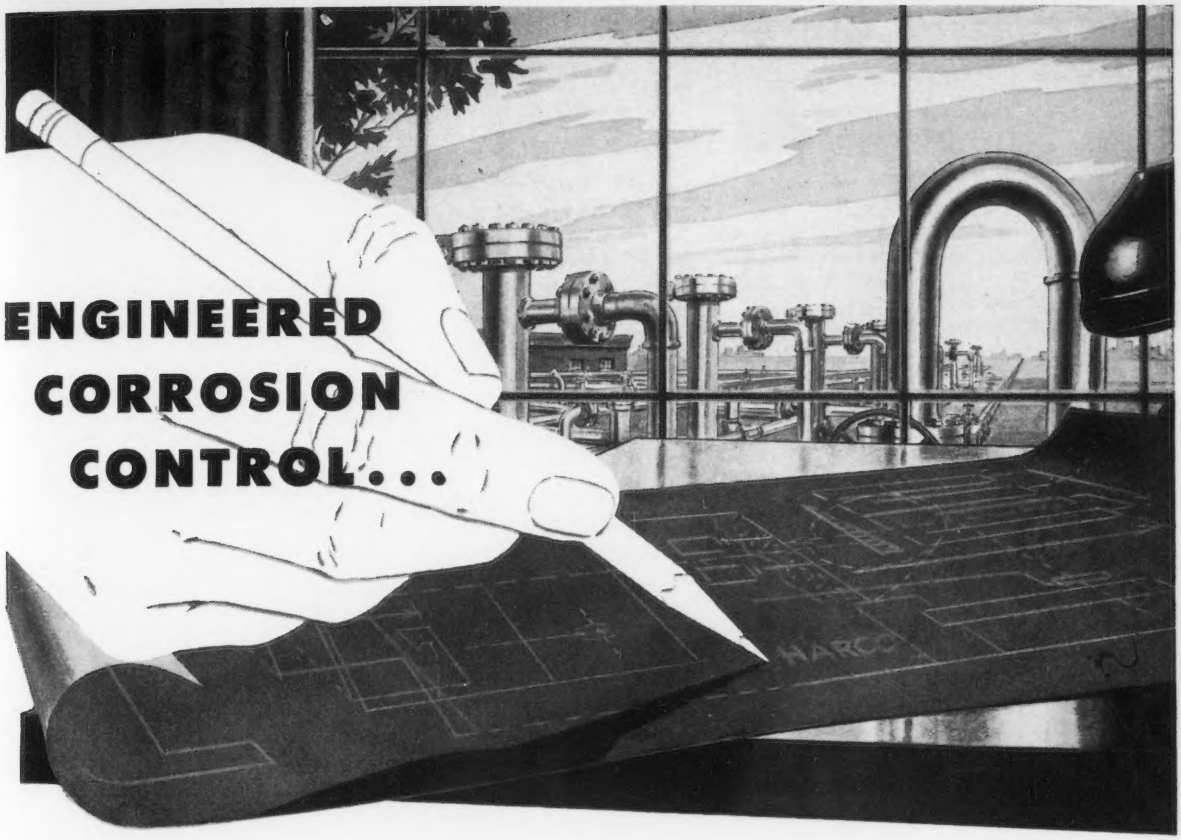
May you continue, as now, to command the admiration and respect of the entire world for many years to come. And may the forces of truth and light, for which you have stood so long, continue to dispel the too-evident clouds of darkness in the world today.

The National Association of Corrosion Engineers is honored to take part in thus acclaiming your past accomplishments and wishes to pledge full cooperation and support in all future endeavors.

A letter of acknowledgment has been received by Mr. Berry as follows from N. H. Furman:

The greeting from the National Association of Corrosion Engineers to the American Chemical Society on the occasion of our Diamond Jubilee is one of the valued mementoes of this event. The celebration has left happy memories in the minds of thousands. In the years to come rereading of the gracious letter from our sister societies, presented at this time, will bring back these recollections.

I was gratified that the society of which you are president could participate in the celebration of our seventy-fifth birthday. It was particularly pleasing to me that you were the representative. The American Chemical Society values the close relations which it has with other scientific and engineering organizations.



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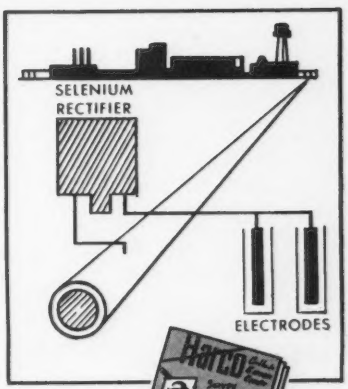
In each application, numerous factors must be considered for maximum cathodic protection. For instance, HARCO engineers check soil conductivity and moisture content, soil water chemical characteristics, dissolved oxygen content, temperature, seasonal variations of environment, protective coatings, dissimilar metals, position of other metallic structures and presence of stray currents.

Results of the HARCO engineered corrosion elimination system include lower maintenance and replacements costs, reduction of "down-time", elimination of excess material for "corrosion factor" lower depreciation rates and greater protection against personal and property damage from hazards caused from corrosion.



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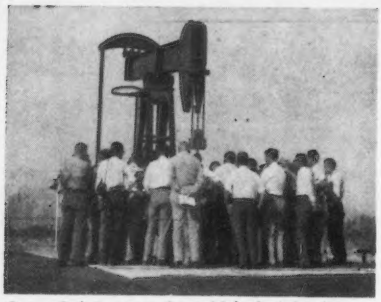
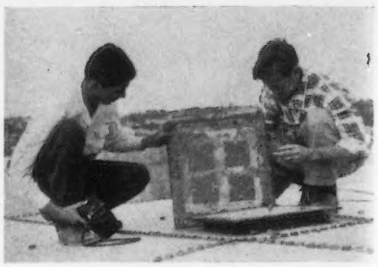


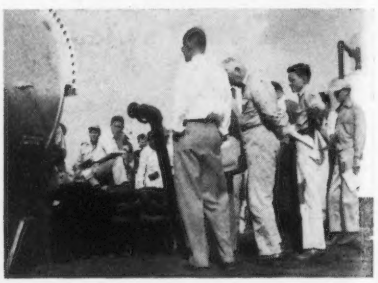
Group 3-A inspects formaldehyde injection apparatus used in "down-the-hole" treatment to control corrosion of rods and tubing.

The tremendous losses from corrosion by sour crude in the West Texas area adjacent to Midland and Odessa were investigated by over 140 engineers attending the 1951 Permian Basin Corrosion Tour October 15 and 16. Permian Basin Section NACE sponsored the event, a continuation of similar tours held in 1948 and 1949, which included inspection of 72 exhibits of tanks, pipelines and well equipment.

Keen interest in methods of protecting metals was expressed by those attending, including some from Wyoming, Illinois, New York, California and Venezuela. Miss Maryann Duggan, of Magnolia Petroleum Company, Dallas, made two of the inspection tours.



John Watts and Dick Overly inspect coupons in roof of 5000-barrel sour crude tank. Ammonia injected since July 25, 1950. No corrosion in evidence.



Group 3-A inspects five tube sections of heater-treater. Deposit inside tubes apparently is ferrous sulfide.

Successful Methods Seen

Considerable success in the use of coatings to control well equipment corrosion was evident. Coated tubing and sucker rods show promise and several methods of down-hole injection of proprietary, polar type organic inhibitors are in use. Formaldehyde also is being used to advantage. Several strings of aluminum rods are being tested.

Lease tanks and gathering lines may be protected economically with internal coatings, including plastics. Several pipe lines internally coated in place with plastic were found to be substantially protected.

An anomaly involving residual protection of tanks from which coatings had been removed for some time may be a subject of study by an NACE committee.

Large Tanks Are Protected

Several large tanks, including some of 55,000 barrel capacity are being protected by injection of anhydrous ammonia in the vapor space. This treatment costing $300 annually for a 55,000-barrel tank is preventing corrosion which previously resulted every seven years in replacement of material costing $10,000.

Nearly every member of the Permian Basin Section served actively during the

(Continued on Page 14)

Sharpe To Head Symposium

L. G. Sharpe of Humble Pipe Line Company, Houston, will be chairman of the Oil and Gas Storage and Transportation Symposium at the NACE 1952 meeting at Galveston, Texas, March 10-14.

ROSKOTE cold-applied anti-corrosion mastic saves time...saves money...SAVES PIPE!

Roskote's drying speed, its handling ease and its high electrical resistivity makes it the ideal mastic for pipeline protection, winter or summer. Whether you are protecting distribution and service lines, or large transmission lines in yard or field, it will pay you to investigate . . .

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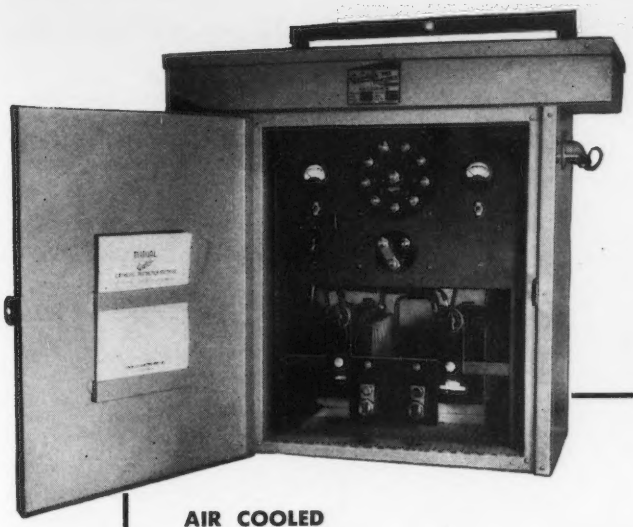

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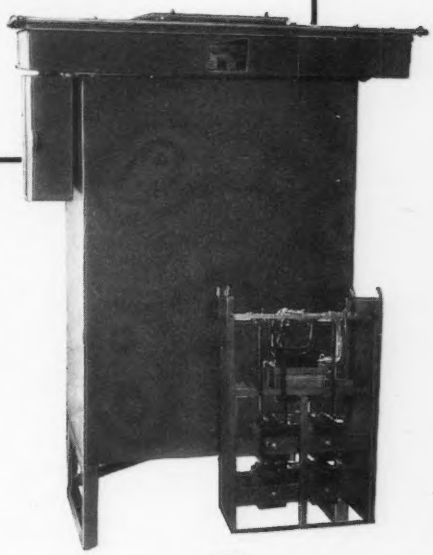

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Eight Papers and Forum Are Scheduled for Los Angeles Meeting

Eight technical papers and one forum have been scheduled for the November 9, 1951, meeting of Western Region at Biltmore Hotel, Los Angeles. The all-day technical session will follow the delivery of the 1951 Marburg Lecture by F. L. LaQue of International Nickel Co.

The titles and authors of scheduled papers are: Morning—Vigilance Underground by Bryan Patterson, Hill, Hubbell & Co., Salt Lake City, Utah; Presentation of Corrosion Control Program to Management by C. W. Shupp, Southern California Gas Co., Los Angeles, Cal.; Relation of Corrosion to Business Costs, by Aaron Wachter, Shell Development Co., Emeryville, Cal.;

Coating Materials and Costs of Coating Applications by Walter H. Cates, Consolidated Western Steel Co., Maywood, Cal.; Luncheon meeting: Some Apparent Anomalies in Corrosion, by F. L. LaQue;

Afternoon—Corrosion of Copper and Metals in Bimetallic Systems, by G. R. Hill, acting head, Department of Fuel Technology, University of Utah, Salt Lake City; Potential Measurements for Estimating Requirements for Cathodic Protection Design, by R. P. Howell, Standard Oil Co. of California, San Francisco, Cal.; Control of Corrosion in Cooling Waters, by R. C. Ulmer, E. F. Drew & Company, New York, N. Y.; Open Forum: Question and Answer Period.

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Failure of Stainless Heater Tubes Is Topic At San Francisco

"Intergranular Failure of Stainless Steel Heater Tubes," was the topic of a talk by George Works, Union Oil Company of California before 35 members and guests of San Francisco Bay Area Section September 12. The dinner meeting was held at El Jardin Restaurant. He discussed failure of Type 316 stainless steel heater tubes in a fired heater at a phenol treating unit where aliphatic constituents are removed from lubricating oil stocks. The failures all occurred after 10 years' service and resulted from intergranular corrosion cracking following sensitization involving carbide precipitation at the grain boundaries. A method of salvaging uncracked tubes by heat treatment was described.

R. P. Howell, Standard Oil Company of California, was appointed to represent the section at the Los Angeles regional meeting.

F. L. LaQue of International Nickel Co., Inc. will speak at the next regular meeting of the section in November. It will be a joint dinner meeting with ASTM.

Local Committees for 1952 Conference Hold Meeting at Galveston

Committees working on local arrangements for the 1952 NACE meeting to be held at Galveston, Texas March 10-14, met at the Galvez Hotel October 4 under Chairman Chas. G. Gribble, Jr. All aspects of the meeting were discussed, with emphasis on entertainment.

A Western motif has been decided on for the banquet, with the entertainment to have a Western touch.

Present besides NACE committee members were representatives of the two conference hotels, the Pleasure Pier where the exhibition and meetings are to be held and the convention manager for the Galveston Chamber of Commerce.

•

Pittsburgh Hears Mears

"Causes of Localized Program," was the topic of an address before Pittsburgh Section October 4 by R. B. Mears, manager of Research and Development Department, U. S. Steel Corp.

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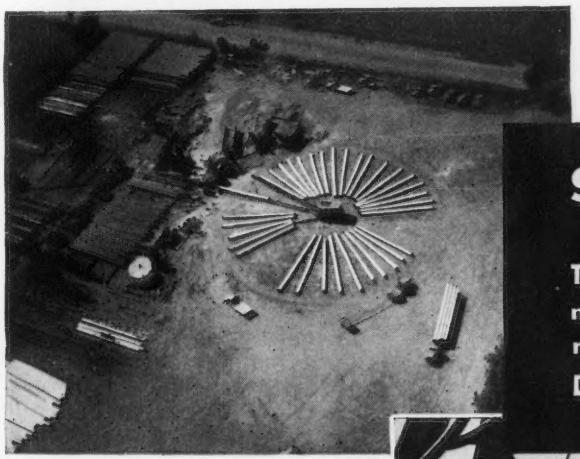

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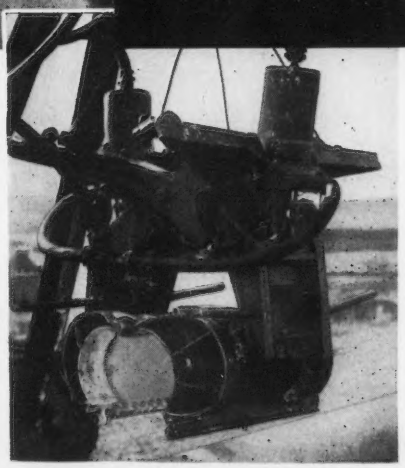

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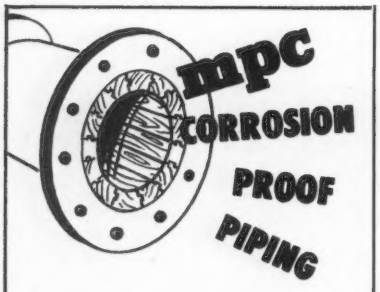
Index to

GENERAL NEWS OF CORROSION INTEREST

	Page
Topic of the Month—A Corrosion-Inhibitive Coating for Lead-Covered Cables *By Wiley D. Sanderson*	1
Williamson Resigns	4
NACE Participates in ACS Diamond Jubilee	8
Sharpe Heads Symposium	10
Local Committees for 1952 Meeting Hold Session at Galveston	12
Copies of Report of Correlating Committee to be Distributed Free	14
Corrosion Problems	15
Book Reviews	16
Maxwell Elected by ASTM	18
New Members, Address Changes	18
Procedure on Correcting NACE Abstract Cards Outlined	22
Emergency Standards Are Approved by ASTM	22
New Products	24
Sessions of Corrosion Interest Scheduled by ASTM	26
Symposium on Testing Metal Powders Is Set	26
Hadley Resigns	26
De-Icing Salts Committee Formed	26
Personals	27



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Copies of Report of Correlating Committee To Be Distributed Free to NACE Members

Bulletins I through IV of the Correlating Committee on Cathodic Protection have been revised and brought up to date and have been published by NACE as a report by the committee. The 48-page 6 x 9 inch book will be distributed free of cost to all members of NACE of record on date of mailing, probably sometime this month, and multiple copies will be sent gratis to sponsor organizations and to a group of companies which subsidized printing of the report. H. H. Anderson, chairman of the committee, has acted to bring about the widest distribution possible of the report, emphasizing that the procedures included have been endorsed as good practice by all concerned.

The report consists of an introduction, "A Billion Dollar Objective," which underlines economic and safety factors involved in the corrosion of underground plant. A table lists the estimates of underground buried structures in the United States at 1,593,000 miles, and annual losses to this plant at about $1 billion yearly.

The four bulletins, all previously published in CORROSION and by the sponsoring organizations in their own format, are:

I—Management Information on Cathodic Protection of Buried Metallic Structures Against Corrosion.

II—Cathodic Protection Notification Procedures.

III—Cathodic Protection Technical Practices.

IV—Joint Cathodic Protection Systems.

An Important Summary

The report constitutes an important and concise summary on the current status of protecting underground plant electrically, with special emphasis on the economic aspects of corrosion losses. One of the purposes of the committee was to make management aware not only of the losses suffered from corrosion but also to underline the fact these losses can be reduced materially through cooperative action. The emphasis on cooperative action is well advised because engineering studies indicate that in proportion to the volume of plant underground and its proximity the necessity for cooperative protection increases. In very complex systems it sometimes is impossible to protect one underground line without affecting one way or another, the balance of the underground structures nearby.

The system of notification procedures set out in Bulletin II formalizes and systematizes what otherwise would be a baffling problem, "How can operators of other plant be notified?" The detailed information given in this bulletin concerning the principal operators of underground plant, sources of reliable maps, and location of regional offices is extremely valuable.

Technical Practices Given

Bulletin III outlines broadly commonly accepted technical practices pertaining to cathodic protection systems. While the data given may not be sufficient for the actual installation of a system, it explains concisely the principal methods and problems likely to be encountered. A reading of this bulletin will impart a well-balanced idea of approved methods of making installations.

Bulletin IV outlines the special problems common to joint cathodic protection systems, showing how, with cooperation, two systems may cooperatively protect their respective structures often at a lower cost than they could be protected separately. The bulletin shows how cooperation can prevent undesirable affects on adjacent systems and suggests a form of agreement between participants in a joint system.

Appendices Useful

The several appendices are useful sources of information. Appendix A lists the names and addresses of 23 joint electrolysis committees; Appendix B, publishers of maps and directories; Appendix C, location of district offices of the American Telephone and Telegraph Company; Appendix D gives locations of Area offices of Western Union Telegraph Company and Appendix E lists technical practices committees of the National Association of Corrosion Engineers dealing with problems relating to cathodic protection.

Appendix F gives a form of Record of Joint Cathodic Protection Installations and Appendix G a selected bibliography on cathodic protection.

Over 140 View—

(Continued from Page 10)

tour, together with many non-members.

Committees Meet

Jack P. Barrett, newly appointed chairman of TP-6E presided at an organizational meeting of his committee October 14 at Odessa. Scope and future activities of the committee were discussed.

TP-18 also held an organizational meeting, approved a scope to include study of internal corrosion in pipe, tanks and other transportation equipment. Internal sour crude corrosion will be studied first by the group.

Group 2-B inspects plastic coated rods in service 18 months without failure.

Corrosion Problems

E. A. TICE, Editor

Corrosion Engineering Section, The International Nickel Co., Inc., 67 Wall St., New York 5, N. Y.

Submit questions and answers for this column in duplicate to the editor. All questions become property of NACE. Questions and Answers may or may not be published under this heading, and may at discretion, be answered by mail directly. Answers to questions are solicited. Authors of questions will remain anonymous to readers while authors of answers may remain anonymous if they request it.

QUESTIONS

No. 15—A very corrosive industrial water is attacking steel pipelines, pumps, etc., and we would like to inquire as to whether such corrosion could be effectively reduced by addition of a corrosion inhibitor. The water is discharged from the plant at a rate of about one million gallons daily. Therefore, to be economical, an inhibitor requirement of from 5 to 30 ppm would have to be suitable.

Details regarding the water are as follows:

1. pH 2.5 to 3.5, but could be raised to 4.0 to 4.5 by chemical treatment.
2. Acid content, by titration, approximately 1 gram per liter as sulfuric acid.
3. Dissolved solids: 6000 mg per liter.

CaO	530 mg/liter
MgO	480 mg/liter
Fe_2O_3 } MnO_2 }	930 mg/liter
Al_2O_3	550 mg/liter
SiO_2	140 mg/liter
Cl	80 mg/liter
Na_2SO_4	400 mg/liter

Balance: Small percentages of sulfides, sulfates, and chlorides, traces of copper.

4. Free oxygen: 6cc/liter.
5. Temperature: 70-90° F.

•

No. 91—In the field of petroleum refining, severe corrosion has occurred in the top section of a straight run fractionating tower constructed of steel. Trays originally ⅜-inch thick lasted only one year and the shell was severely pitted after two years.

The crude oil being processed had a gravity of 20 to 26. The sulfur content varied from 1.3 to 2.5 and the salt content from 15 to 30 pounds per 1000 bbl. The total sulfur in the gasoline varied from 0.12 to 0.40 per cent. The temperature at the top was maintained at 300 degrees to 340 degrees F, and 18 per cent gasoline was being produced.

What alloy material can be chosen for longer life of this tower?

•

No. 92—A stainless steel sheet and tube heat exchanger was installed with brackish water flowing through the tubes as the cooling medium. Tube failures due to pitting necessitated retubing, and 70/30 cupro-nickel tubes have been installed. Can we expect any serious galvanic corrosion between the stainless steel tube sheet and head and the 70/30 cupro-nickel tubes, under continuous flow conditions?

"Man on Land" Film

A 16-minute animated motion picture available in either 16mm or 35mm entitled "Man on the Land" has been produced under sponsorship of the Oil Industry Information Committee of the American Petroleum Institute, 50 West 50th St., New York 20, N. Y. The film tells the history of man's progress in agriculture emphasizing that progress and prosperity have been possible only in a free and competitive environment. It is available for showing by societies and associations.

Manning Addresses Annual Cleveland Dinner

Paul V. D. Manning, vice president of International Minerals and Chemicals Company, was scheduled to be principal speaker at the November 9 Third Annual Dinner of the Chemical Professions in Cleveland held at Hotel Hollenden. The annual event, sponsored by local units of the American Chemical Society, American Institute of Chemical Engineers, Electrochemical Society and American Institute of Chemists, is designed to advance the chemical professions in the Northern Ohio area.

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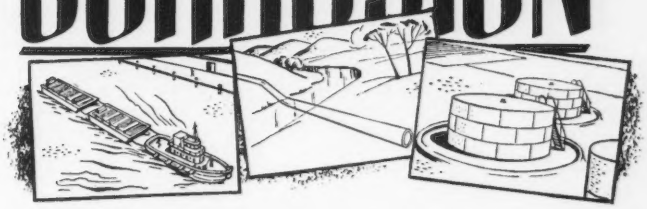

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BOOK REVIEWS

TEXTBOOK OF ELECTROCHEMISTRY. Volume I. By G. Kortum and J. O'M. Bockris. 351 pages 6¼x9⅜ inches, cloth. The Elsevier Press, 402 Lovett Blvd., Houston, Texas. Per Copy.....$7.00

This English translation of the textbook in German by G. Kortum, professor of Physical Chemistry, Tubingen University and J. O'M. Bockris, lecturer in physical chemistry, Imperial College of Science and Technology, University of London is based on "Lehrbuch der Elektrochemie," Second German Edition, 1949.

In the foreword to the English edition the authors stress the book is designed to give a clear understanding of fundamentals, rather than a superficial description of all the many parts of the field. About half the material is new compared to the German edition. While the book is designed as a text book, bibliographies at the ends of sections have been extended and revised to include English language work, and a new chapter on practical information and data useful to the electrochemist has been added.

The book covers definitions and fundamental laws, essentials of chemical thermodynamics, the solvation of ions, weak and strong electrolytes, the theory of interionic attraction, results and applications of conductance measurements, electromotive force, practical applications of potentiometric measurements and equilibria in solutions of weak electrolytes.

Subject index and about 100 problems and solutions are in Volume II.

•

CORROSION CAUSES AND PREVENTION. By Frank N. Speller. 686 pages, 6x9 inches, cloth. Third Edition. McGraw-Hill Book Company, Inc., 330 West 42nd St., New York 18, N. Y. Per Copy.....$10.00

This third edition of Dr. Speller's popular treatise on corrosion is designed not only to be a source of help to engineers engaged in corrosion control but also to those others who will find it useful in solving specific corrosion problems. Dr. Speller says in his foreword that developments in the knowledge of corrosion, particularly in its prevention have been truly remarkable, necessitating extensive revision and additions to the book.

The book endeavors to give a comprehensive review of the subject for the general reader with no more technical language than necessary for a sound understanding of corrosion problems. A general bibliography is not included in this edition because current monthly biblographies are now available. New sections on biological influences and cathodic protection have been added.

Dr. Speller not only gives general principles underlying corrosion phenomena, including a chapter on corrosion testing, but he devotes the second part of his work to preventive measures, which cover mitigation underwater, in closed water systems, steam generators, steam and hot water heating systems, chemical industries, underground, stray currents and cathodic protection.

•

CORROSION GUIDE. By Erich Rabald. 629 pages, 6x9½ inches. Cloth. The Elsevier Press, 402 Lovett Blvd., Houston, Texas. Per Copy $12.50

This book consists principally of tables of information arranged to give the engineer a survey of the corrosion resistance of materials versus corrosives. Corrosives are alphabetically arranged vertically on a fly-fold at the beginning of each series of data in such a way that pages listing materials horizontally may be brought successively into juxtaposition with the corrosives. This arrangement permits a rapid comparison of the merits of the materials catalogued with the various corrosive media listed.

The purpose of the book is to provide a ready means whereby the engineer may learn what material is best suited for a given corrosive environment and at the same time compare with the best material other not-so-desirable materials it may be necessary to use for economic or other reasons. More than 250 corrosives and more than 40 materials of construction are compared in a manner similar to the Dechema tables of materials which have appeared in Germany.

A bibliography and index are included.

•

PROCEEDINGS OF THE SECOND MEETING OF THE INTERNATIONAL COMMITTEE OF ELECTROCHEMICAL THERMODYNAMICS AND KINETICS. 408 pages, 6¾x9⅜ inches, Cloth. Libreria Editrice Politecnica Cesare Tamburini, via G. Pascoli, 55, Milano, Italia. (Papers are published in the languages of the authors.)

Per copy, Lire.....3,800

Proceedings of this international meeting of scientists interested in electrochemical thermodynamics held at Pallanza, Italy, 18 September 1950 are published in this volume. The material is arranged in sections with each author's contribution published in the language in which it was given.

Attending from the United States were R. H. Brown, Aluminum Co. of America, New Kensington, Pa.; Paul Delahay, Louisiana State University, Baton Rouge: G. A. Murdock, and Pierre Van Rysselberghe, University of Oregon, Eugene; R. D. Williams, Aluminum Co. of America, New Kensington, Pa.

•

REPORT OF THE DUTCH COMMITTEE II FOR THE STUDY OF SOIL CORROSION AND PROTECTION OF PIPE LINES. 70 Pages, 5¾x8 inches, paper. Central Institute for Research on Materials, P. O. Box 49, Delft, Holland. Corrosion Department. Subject: Specifications for the Coating of Cast Iron and Steel Pipes with a Nominal Passage of at Least 75mm with Blown Asphalt Bitumen. Per Copy..hfl. 6

The book covers several recommended classes of protection using asphaltic bitumen and one or more wrappings of asbestos, woolfelt, glass fiber cloth, jute and others. Specifications and recommendations for surface preparation, application techniques, materials handling, factors determining selection of classes of protection, pipe materials, stray currents, preparation of solutions, wrapping materials, retreatment of pipes, coating testing, and other points are covered. This is an English translation of Communication No. 13 of the Institute.

ANNUAL REPORT OF THE NATIONAL BUREAU OF STANDARDS FOR 1950. NBS Miscellaneous Publication 200, 113 pages. Government Printing Office, Washington 25, D. C. Per Copy.....50c

Summarizing the scientific investigations conducted by the National Bureau of Standards during the fiscal year 1950, the illustrated booklet contains accounts of current activities as well as more detailed descriptions of especially important scientific developments.

The scope of research and development at the NBS, both theoretical and practical, is indicated by the names of the 13 scientific and technical divisions: electronics, atomic and radiation physics, chemistry, mechanics, organic and fibrous materials, metallurgy, applied mathematics, mineral products, building technology, heat and power, electricity and optics, metrology, and radio propagation.

Among accomplishments during the year were the NBS Eastern Automatic Computer, SEAC, the fastest general-purpose, automatically sequenced electronic computer now in operation; the NBS Electronic Currency Counter, designed for the Treasury Department to count old paper money at an hourly rate of 30,000 bills; and the highly precise omegatron, which discriminates between atomic particles of different masses.

(Note: Foreign remittances must be in U. S. exchange and should include an additional one-third the publication price to cover mailing costs.)

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NACE

New Members and Changes of Address

• This list is published principally for use by NACE Regional and Sectional officers in keeping their mailing lists up to date.

NEW MEMBERS

(Additions Through September 27, 1951)

CALIFORNIA

SCHUSTACK, EDWARD H., R. H. Baker & Co., Inc., 2070 East Slauson Ave, Huntington Park, California.

BIREN, JACK A., The Texas Company, P. O. Box 320, Long Beach 1, Cal.

GRAGG, WILLIAM B., Taylor Forge & Pipe Works, 225 Bush, San Francisco, Cal.

LOMBARDO, FLORA, Amercoat Corporation, Atlantic & Firestone, Southgate, Cal.

FLORIDA

JOHNSON, CLEMENT O., Seaboard Air Line Railroad Co., 322 West Bay St. Jacksonville, Florida

GEORGIA

MOBLEY, GARNER C., Union Bag & Paper Corp., Box 570, Savannah, Georgia

ILLINOIS

RAMSAY, CLAYTON W., The Texas-Empire Pipe Line Co., P. O. Box 664, Bloomington, Illinois

GATES, HARRISON L., Kaiser Aluminum & Chemical Sales, Inc., 919 N. Michigan, Chicago 11, Illinois

JANKE, PETER L., Chicago Transit Authority, Eelectrical Dept., 79 West Monroe, Chicago 90, Illinois

ROSE, PHILIP E., 6930 South Shore Drive, Chicago 49, Illinois

PRICE, F. CARR, Victor Chemical Works, 11th & Arnold Sts., Chicago Heights, Ill.

INDIANA

HARBAUGH, R. L. RES. & DEV. DEPT., Inland Steel Company, Indiana Harbor Works, East Chicago, Indiana

KOPPLIN, JULIUS O., Northern Indiana Public Service Co., 5265 Hohman Avenue, Hammond, Indiana

IOWA

DANIELS, FRED A., JR., Electro Rust-Proofing Corp. (N. J.), 1085 27th Street, Des Moines 11, Iowa

LOUISIANA

BLUMER, ADAM F., Esso Standard Oil Co., P. O. Box 551, Baton Rouge, Louisiana

VOGLER, GUS, Dowell Incorporated, P. O. Box 264, Lafayette, Louisiana

DOWE, ROBERT J., Southwestern Bell Tel. & Tel. Co., 820 Poydras St., New Orleans, Louisiana

INGRAM, SIDNEY M., Turco Products, Inc., 1305 Marshall St., Shreveport, Louisiana

MASSACHUSETTS

SOLEY, R. CLYNE, Dewey & Almy Chemical Co., 62 Whittemore Ave., Cambridge, Massachusetts

LORBER, ROBERT P., American Tel. & Tel. Co., 145 State St., Springfield, Mass.

MISSOURI

BESTER, CLARENCE A., Independent Technical Service, Inc., 1701 Syndicate Trust Bldg., St. Louis 1, Missouri

NEW JERSEY

OSBORNE, EARL H., The Bayer Co., Div., Sterling Drug, Inc., 2144 East State St., Trenton 7, New Jersey

NEW YORK

BISHOP, ROBERT W., Harrison Radiator Division, G. M. C., Washburn, Lockport, New York

BLACK, Wm. RALSTON, Koppers Co., Tar Products Div., 5900 Empire State Bldg., New York, New York

GUNTER, EDGAR J., Anderson-Prichard Oil Corp., 420 Lexington Ave., New York 17, New York

REID, JAMES B., The Dow Chemical Co., 30 Rockefeller Plaza, New York 20, New York

WRIGHT, C. I., Shell Chemical Corp., 50 West 50th St., New York 20, New York

WRIGHT, HERBERT J., Ref. Eng. Div., Socony-Vacuum Oil Co., 26 Broadway, New York 4, New York

OHIO

POWELL, CECIL W., Republic Steel Corporation, 410 Oberlin Ave., S.W., Massillon, Ohio

OKLAHOMA

GOODELL, ROBERT E., Phillips Petroleum Co., Adams Building, Bartlesville, Okla.

McAULIFF, JOHN P., 2033 Westchester Drive, Oklahoma City, Oklahoma

BLEDSOE, C. C., Midwestern Constructors, Inc., 105 North Boulder, Tulsa 3, Okla.

HORTON, C. ROY, Research Control Instrument Company, 8211 East 7th St., Tulsa, Oklahoma

HUDGENS, ELLSWORTH W., Dowell Inc., Kennedy Building, Tulsa, Oklahoma

PENNSYLVANIA

LeCOFF, JESSE, Catalytic Construction Co., 1528 Walnut St., Philadelphia, Pa.

GRAHAM, H. W., Jones & Laughlin Steel Corp., Third Ave. & Ross St. (Jones & Laughlin Bldg.) Pittsburgh 30, Pa.

HARMAN, GEORGE ROBERT, H. J. Heinz Company, Progress Street, Pittsburgh, Pa.

McCULLOUGH, ORGAIN E., JR., Pittsburgh Coke & Chemical Co., 1720 Grant Bldg., Pittsburgh 30, Pennsylvania

RAITHEL, EDWARD E., Pittsburgh Coke & Chemical Co., Grant Bldg., Pittsburgh, Pa.

TENNESSEE

FINCHER, ROBERT K., The Quaker Oats Company, Chemical Plant, P. O. Box 6835, Hollywood Station, Memphis 8, Tenn.

TEXAS

GRAESER, HENRY J., Dallas City Waterworks, 2125 Commerce, Dallas, Texas.

EMERY, D. T. JOHN, Rio Grande Valley Gas Co., 335 West Elizabeth, Brownsville, Texas

SHOEMAKER, RAYMOND T., Oil Well Supply Co., 2001 N. Lamar, Dallas 1, Texas

SLOVER, CHARLES L., Reilly Tar & Chemical Corp., 3951 Buena Vista, Apt. No. 2, Dallas 4, Texas

LYONS, WILLIAM C., Plastic Eng. & Sales Corp., Box 1037, Fort Worth, Texas

BROCK, JAMES R., 2158 Pelham, Houston 19, Texas

GREER, NORMAN E., Norman E. Greer Company, 1208 Pease, Houston, Texas

HOLMBERG, M. E., 4101 San Jacinto St., Houston 4, Texas

MICKELSON, ALFRED O., The Bestar Company, 2419 Travis St., Houston 6, Texas

NEIL, FRANK M., Marshall, Neil & Pauley, Inc., 811 York St., Houston 3, Texas

OWENS, HOWELL C., Coast Paint & Lacquer Co., Inc., 6901 Cavalcade St., Houston, Texas

SLONEK, OTTO F., Industrial Chemical Service, Inc., 1113 Hub, Houston 23, Texas

CHANGES OF ADDRESS

(Old Address Follows New in Parenthesis)

ALABAMA

STEVENSON, KENYON, JR., Rohm & Haas Co., Redstone Arsenal Research Div., Huntsville, Alabama. (3414 North 19th Street, Philadelphia 40, Pennsylvania.)

CALIFORNIA

JENKINS, VANCE N., Research Center, Research Laboratory, Union Oil Co., P. O. Box 218, Brea, California. (Wilmington, Cal.)

(Continued on Page 20)

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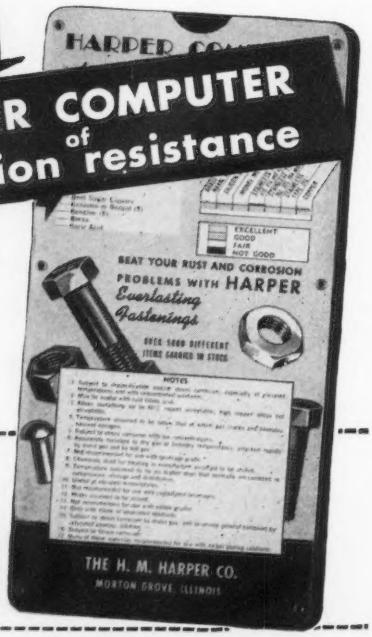

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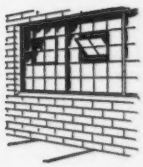

Changes of Address—

(Continued From Page 18)

JENKINS, VANCE N., Union Oil Co., 617 West 7th St., Los Angeles 17, Cal. (P. O. Box 758, Wilmington, Cal.)

SNYDER, FREDERICK JOSEPH, 8112 Chicapee Ave., Northridge, Cal. (Southern California Gas Co., 2306½ Pisani Place, Venice, Cal.)

RIDOUT, ROBERT P., Southern Counties Gas Co., P. O. Box 1691, San Pedro, Cal. (P. O. Box 217, Foy Station, Los Angeles 17, Cal.)

DELAWARE

DEACONSON, JAMES N., 19 W. 38th St., Wilmington, Delaware. (1601 Todd's Lane, Wilmington 28, Delaware.)

FLORIDA

BERGMAN, ALFRED C., Protective Coatings, Inc., P. O. Box 2578, Tampa, Florida. (807 N. Fremont Ave., Tampa, Florida.)

VALDESPINO, RAMON, Twentieth Century Builders Corp., P. O. Box 2578, Tampa, Florida. (807 N. Fremont Ave., Tampa, Florida.)

GEORGIA

JOHNSTON, J. FLYNN, American Tele. & Tel. Co., 1139 Hurt Bldg., Atlanta 3, Georgia. (Rm. 909, 51 Ivy Street, N. E., Atlanta 3, Georgia.)

ILLINOIS

JENSEN, O. L., Public Service Co., of Nor. Ill., 615 Eastern Ave., Bellwood, Illinois. (1001 So. Taylor, Oak Park, Ill.)

MARKLE, MATHEW G., Public Service Co. of Northern Ill., 615 Eastern Ave., Bellwood, Ill. (1001 South Taylor Avenue, Oak Park, Ill.)

NICHOLS, LAURIE E., Public Service Co. of No. Ill., 615 Eastern Ave., Bellwood, Illinois. (1001 South Taylor Ave., Oak Park, Ill.)

OTT, LAWRENCE H., Rheem Mfg. Co., 7600 S. Kedzie Ave., Chicago, Ill. (Res. Lab., 4361 Firestone Blvd., South Gate, Calif.)

TODD, RAYMOND W., JR., 6300 No. Oakley, Chicago 45, Ill. (4614 No. Paulina, Chicago 40, Illinois.)

SMITH, WINSTON G., c/o Geyer Manufacturing Co., Rock Falls, Ill. (A. O. Smith Corp., 8309 Pritchard Place, New Orleans, Louisiana.)

KANSAS

BUSCH, PAUL E., C. E. Wilson Const. Co., 1401 Fairfax Trewy, Kansas City, Kansas. (Texas Eastern Transmis. Corp., P. O. Box 1612, Shreveport 94, Louisiana.)

KENTUCKY

BRADY, THOMAS E., 1335 Claranette Court, Apt. C, Owensboro, Kentucky. (114 New Street, Cranford, New Jersey.)

LOUISIANA

TUGGLE, RAY, 124 Evangeline Drive, Lafayette, Louisiana. (1917 Prospect, Houston, Texas.)

BROWN, VERNON M., Columbia Southern Chemical Corp., Box 900, Lake Charles, Louisiana. (Southern Alkali Corporation.)

TOMB, H. H., Columbia Southern Chemical Corp., P. O. Box 900, Lake Charles, Louisiana. (Southern Alkali Corporation.)

WOODMAN, FRANK W., Columbia Southern Chemical Corp., P. O. Box 900, Lake Charles, Louisiana. (Southern Alkali Corporation.)

NEWTON, WILLIAM E., 1204 Napoleon Ave., Apt. No. 1, New Orleans 15, Louisiana. (2174 Chesterland Ave., Lakewood 7, Ohio.)

MASSACHUSETTS

TIBBETTS, E. F., Wollaston Brass & Aluminum Foundry, 31 Fayette St., North Quincy, Massachusetts. (The Lummus Company, 385 Madison Ave., New York 17, New York.)

MISSOURI

FITZPATRICK, ALLYN H., 5021 Troost Avenue, Kansas City, Missouri. (Great Lakes Pipe Line Co., Drawer 2239, Kansas City 13, Missouri.)

NEVADA

CLOYES, WILLIAM P., Titanium Metals Corp. of America, P. O. Box 2128, Henderson, Nevada. (National Lead Co., Titanium Div., P. O. Box 125, Boulder City, Nevada.)

NEW JERSEY

GRAY, A. E., Brooklake Road, Florham Park, New Jersey. (Pipe Protection Service, Inc., 10-12 Center St., Elizabeth 4, New Jersey.)

DICKINSON, L. R., Socony-Vacuum Oil Co., Inc., Eastern Pipe Line Div., P. O. Box 989, Plainfield, New Jersey. (26 Broadway, New York 4, New York.)

NEW YORK

ANDREW, HAROLD O., Moore-Publishing Co., Inc., 48 West 38th Street, New York 18, New York. (9 East 38th St., New York, N. Y.)

EPSTEIN, LEONARD, 801 West End Ave., New York 25, New York. (Stevens Institute of Tech., Castle Point, Hoboken, New Jersey.)

OHIO

GEGNER, PAUL J., Columbia-Southern Chemical Corp., Barberton, Ohio. (Pittsburgh Plate Glass Co., Columbia Chemical Division.)

LOWERRE, R. T., American Steel & Wire Co., Room 822, Rockefeller Bldg., Cleveland 13, Ohio. (Union Commerce Building, Cleveland 14, Ohio.)

SCANLON, D. A., American Steel & Wire Co., 706 Rockefeller Bldg., Cleveland 13, Ohio. (Union Commerce Building.)

OKLAHOMA

ROBERTS, JOHN P., PROF., Dept. Eng. Metallurgy, College of Engineering, University of Oklahoma, Norman, Oklahoma. (University of Houston, 3801 St. Bernard St., Houston 4, Texas.)

BOST, ARMON H., COLONEL, 122 E. 25th St., Tulsa, Oklahoma (306th Logistical Command, Camp McCoy, Wisconsin.)

CAMPBELL, J. G., Deep Rock Oil Corp., P. O. Box 1051, Tulsa, Oklahoma. (1005 Atlas Life Bldg.)

PENNINGTON, LOUIS E., MGR., Reynolds Metals Company, 214 Boulder Bldg., Tulsa 14, Oklahoma. (310 Thompson Bldg., 20 E. 5th St., Tulsa 3, Oklahoma.)

PENNSYLVANIA

HAMILTON, HUGH L., The A. V. Smith Co., 370 Trevor Lane, Bala-Cynwyd, Pennsylvania. (Keystone Pipe Line Co., 260 S. Broad St., Philadelphia, Penna.)

WILSON, JOHN R., 1422 Kansas Ave., White Oak, McKeesport, Pennsylvania. (555 McCully St., McKeesport, Pennsylvania.)

KOPPL, FREDERICK, c/o E. B. Curdts, James G. Biddle Co., 1316 Arch St., Philadelphia 7, Pennsylvania. (James G. Biddle Co., Suite 602, 20 West Jackson Blvd., Chicago 4, Illinois.)

POGACAR, C. F., Atlantic Refining Co., 260 S. Broad St., Philadelphia 1, Pennsylvania. (416 Olympia Road, Pittsburgh 11, Pennsylvania.)

BIALOSKY, JEROME M., Koppers Co., Inc., Koppers Bldg., Pittsburgh 19, Pennsylvania. (United States Steel Co., 234 Atwood Street, Pittsburgh 13, Pennsylvania.)

FELLER, EUGENE W. F., 30 Shady Drive West, Pittsburgh 28, Pennsylvania. (Maujer Publishing Co., 826 Greenwood Ave., St. Joseph, Michigan.)

(Continued on Page 22)

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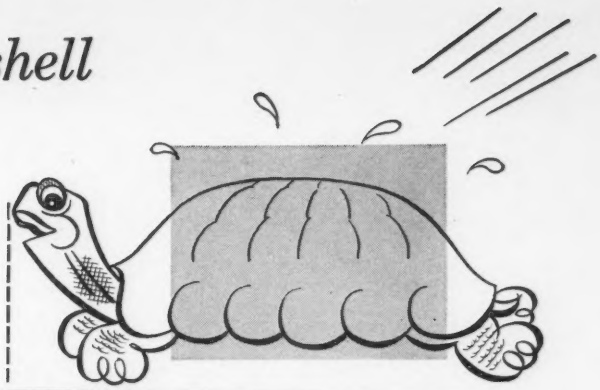

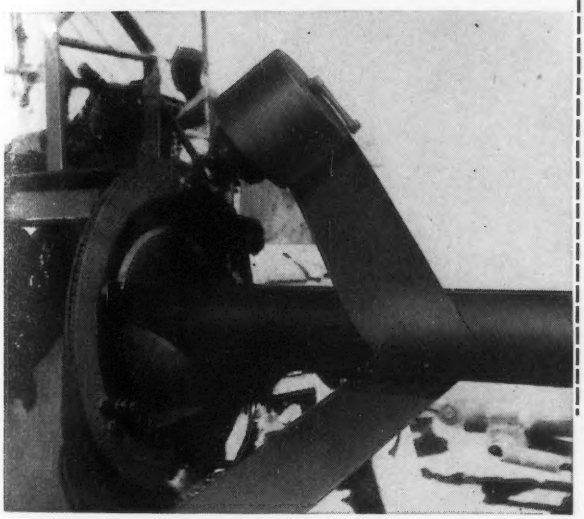

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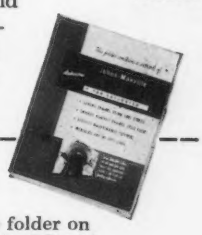

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(Continued from Page 20)

BENNUNG, KARL, JR., 511 Sheffield Drive, Springfield, Del. Co., Pennsylvania. (Gates Engineering Co., Box 1711, Wilmington, Delaware.)

WEST VIRGINIA

GEARY, ARTHUR L., Quality Control, Weirton Steel Co., Weirton, West Virginia. (Research Asst. Corrosion Lab., Mit., Rm. 8-206, Mass. Institute of Tech., Cambridge, Massachusetts.)

TEXAS

PHILLIPS, CECIL, JR., 1506 E. Texas Ave., Baytown, Texas. (Humble Oil & Refining Co., Box 3536.)

WINEGARTNER, E. C., Maintenance Eng. & Insp. Dept., Humble Oil & Refining Co., Baytown, Texas. (3417½ Michigan St., Baytown, Texas.)

WATKINS, JESSE L., Shell Pipe Line Corporation, 1424 Elm St., Colorado City, Texas. (2142 Locust.)

HAMLIN, GEORGE O., 854 Erwin Ave., Corpus Christi, Texas. (Hamlin Painting Company, Box 697, Aransas Pass, Texas.)

MOFFATT, THOMAS S., JR., Columbia-Southern Chemical Corp., Lawrence Drive, Corpus Christi, Texas. (Southern Alkali Corporation.)

POLHAMUS, JOHN R., PLANT SUPT., Columbia-Southern Chemical Corp., P. O. Box 4026, Corpus Christi, Texas. (Southern Alkali Corporation.)

MOORE, EARL D., 3916 Dempster Ave., Dallas 11, Texas. (7427 Brockley, Houston 17, Texas.)

BENDER, RICHARD B., 634 W. Temple, Houston 9, Texas. (Tennessee Gas Transmission Company, 519 Iowa Ave., Clarksdale, Mississippi.)

BOOTH, ROBERT C., 5719 South Seas, Houston, Texas. (7220 Village Way, Houston 17, Texas.)

BOWMAN, MACK M., 4620 Telephone Road, Houston 17, Texas. (Colombian Petroleum Co., Apartado 100, Cucuta Colombia, S. A.)

NELSON, OTIS A., 1253 Archley Drive, Houston, Texas. (5026 Marietta, Houston, Texas.)

RICHARDS, S. L., JR., Rosson-Richards Company, 801 M & M Bldg., Houston, Texas. (Shell Building, Houston 2, Texas.)

POOLE, CHARLES L., Box 4107, Texas Tech. Station, Lubbock, Texas. (West Texas Gas Co., P. O. Box 1111, Midland, Texas.)

NEWELL, THOMAS M., 212 Santa Rita, Odessa, Texas. (Stanolind Oil & Gas Co., 1136 N. Lewis, Tulsa, Oklahoma.)

KEHN, G. RAY, 1612 15th St., Orange, Texas. (304 Pine St.)

WILSON, FRED V., Standard Brass & Mfg. Co., P. O. Box 1469, Port Arthur, Texas. (705 Milam Street, Beaumont, Texas.)

GOODRICH, C. R., 1446 West Summit Avenue, San Antonio 1, Texas. (260 Post Ave., San Antonio 2, Texas.)

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Procedure on Correction Of NACE Abstract Card Errors Is Outlined

NACE Central Office has set up a procedure for issuing corrected cards to replace Corrosion Abstract Punch Cards containing errors. When a significant error is discovered Central Office will reprint the card after making necessary corrections. This corrected card will have the same NACE abstract card number as the incorrect card, but the number will be followed by the word "Revised". Following the printed text of the abstract a note will be added stating the card is a revised one which should be substituted for the incorrect card previously mailed.

In order to make obvious the necessity of substituting corrected cards for those containing errors, revised cards will be placed on top of the lowest serial card in a subsequent shipment, with an attached notice calling attention to it.

Subscribers who discover significant errors in cards are asked to notify NACE Central Office.

California Municipal Utilities Meeting Is Scheduled for Nov. 13-16

The 19th Annual Conference of the California Municipal Utilities Association will be held in Oakland, Cal. November 13-16, 1951 with headquarters at Hotel Leamington.

November 14 and 15 will be devoted to a series of addresses of interest to utilities ranging from accounting, through standardization to "Material Control and Conservation," one of three round table topics to be discussed under chairmanship of Floyd L. Goss, engineer of overhead distribution, Department of Water and Power, Los Angeles.

J. H. McCambridge, general manager of Public Service Department, Burbank, Cal. is president of the association.

Emergency Standards Are Approved by ASTM

Recently approved emergency alternate provisions by the American Society for Testing Materials have been announced as follows:

Specifications for: Seamless Cold Drawn Intermediate Alloy Steel Heat-Exchanger and Condenser Tubes, Seamless Intermediate Alloy Steel Still Tubes for Refinery Service, Welded Alloy Steel Boiler and Superheater Tubes, Seamless Alloy Steel Boiler and Superheater Tubes, Seamless and Welded Austenitic Stainless Steel Tubing for General Service, Seamless and Welded Austenitic Stainless Steel Sanitary Tubing, Seamless Austenitic Chromium-Nickel Steel Still Tubes for Refinery Service, Seamless and Welded Austenitic Seamless Steel Pipe.

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Technical material on Corrosion from any source will be considered by the NACE Editorial Review Committee. Information on requirements of the association as to form of papers may be obtained on application to Central Office, Houston.

ANACONDA Arsenical Admiralty—

a practical solution to tube dezincification

What causes dezincification?

Metallurgical research indicates a number of conditions causing dezincification of condenser and heat exchanger tubes:

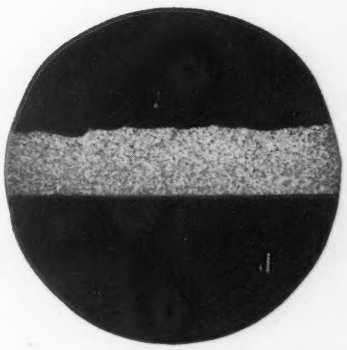
LAYER TYPE dezincification tends to be the result of a critical degree of acidity of the cooling water.

PLUG TYPE dezincification is more apt to occur where the cooling water is neutral or alkaline.

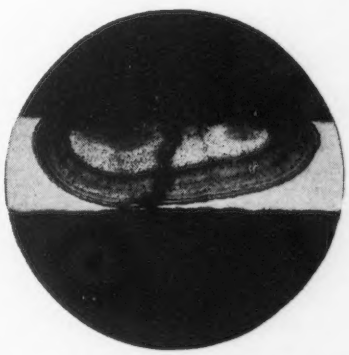
LOW WATER VELOCITY may accelerate the loss of zinc by failing to wash away copper salt solutions, thereby permitting redeposition of copper.

HIGH COOLING WATER TEMPERATURES hasten over-all corrosion reactions and seem to favor the electrochemical process causing redeposition of copper.

LOW OXYGEN CONTENT of cooling water is also considered a factor in accelerating the redeposition of copper. 51127



Longitudinal section through Arsenical Admiralty tube. No evidence of dezincification. Upper surface is waterside. 7x.



Longitudinal section through wall of non-Arsenical Admiralty tube showing dezincification plug starting from waterside (upper surface). 7x.

Arsenic as an Inhibitor

Laboratory studies and field installations have clearly indicated the effectiveness of small quantities of arsenic in Admiralty and other copper alloys as an inhibitor to dezincification. The inhibiting action of arsenic, as well as of other inhibitors, is not well understood. One theory holds that the inhibitor covers anodic areas to prevent initial selective corrosion; another states that it forms a film of an electropotential equal to that of the copper to prevent the copper redepositing.

For Technical Counsel

The files of Anaconda's Technical Department and the experience of its engineers cover the case histories of condenser and heat exchanger tubes operating under the widest variety of conditions. These are freely available to you to help you select the right alloy for your installation. The American Brass Company, Waterbury 20, Connecticut. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario.

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Heat Treat Scale is removed and preparation of a strip surface for name etching is done simultaneously with automatic brush processes developed by Osborn Manufacturing Co., Cleveland, Ohio. The strip passes through the Osborn brushes at 50 feet a minute while brushes rotate at 3450 rpm, doing the work with two stations formerly requiring six.

•

Chilling Steel to 120 degrees F in Sub-Zero Industrial Chilling Machines, a division of Deepfreeze Distributing Corp., Cincinnati 29, Ohio, transforms the austenite to martensite, improving dimensional stability, giving greater hardness, strength and ductility.

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Paratex, a rubber-base, one-coat interior wall and ceiling soft matte finish paint is being produced by Truscon Laboratories, 1700 Caniff Ave., Detroit 11, Mich.

•

Series 21 Quick Coupling stainless steel clamps have a new hinged latch for quick assembly or removal. Designed by the manufacturers Specialty Products Co., 1965 East 66th St., Cleveland 3, Ohio for high temperature, pressure and corrosion resistance, they make efficient seals.

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Dekoron tubing in square, triangular, oval and streamlined shapes has been added to standard round sizes by Moore & Co., Mantua, Ohio.

•

Magnus 751, a new all-purpose metal cleaner has been developed by Magnus Chemical Co., Garwood, N. J. Manufacturers state the cleaner is safe for all metals and will not attack, pit or mar aluminum alloys, cadmium, solder, die cast or soft metals. It is non-flammable and has unusually long life. It is used successfully in removing carbonized oil and gums from aircraft engine parts, Diesel engine parts. The material closely follows Navy Aeronautical Specification C-86 and Army-Navy Aeronautical Specification AN-C-163.

•

Burdett Burn-Off Process prepares metal parts for finishing with radiant heat. The cycle of 5 to 8 minutes assures a product free from oil, grease or other impurities in seams or joints. The 650 to 675 degree temperature is said to produce a surface with superior adhesion qualities for finishing with an excellent rust inhibiting surface on the metal.

•

Polyethylene impregnated paper bags produced by Bemis Bros. Bag Co., 408 Pine St., St. Louis 2, Mo. may be used to store a wide range of substances, including compost, quick lime, caustic soda, phosphates and others. Capacities are up to 100 lb.

•

Between 5000 and 10,000 tons of scrap metal will be recovered from the 115-acre site of the U. S. Pipe and Foundry Company plant at Addyston, Ohio. Monsanto Chemical Company, purchasers of the plant, destined to be a source of Lustrex styrene and Resinox phenolic resins, will grade the site after recovery of the scrap, which was buried at various places during 75 years.

•

Wallex, an oxy-acetylene hard facing alloy composed of chromium, molybdenum, manganese, silicon, carbon and iron has excellent impact, abrasion and corrosion resistance among other qualities, according to Wall Colmonoy Corp., 19345 John R Street, Detroit 3, Mich.

•

Carpenter Steel Co., Alloy Tubes Division, Union, N. J. offers a 12x9 inch wall card giving useful corrosion resistance information for several analyses of stainless steel tubing and pipe. Corrodents ranging from fresh water and blood to sulfuric and hydrochloric acid are listed with the recommended alloys for use with each. Carpenter also has purchased the Webb Wire Works, manufacturers of needle wire, stainless steel spring wire and other specialties down to .0025-inch D.

•

Vacuum Impregnation is described in a comprehensive book by F. J. Stokes Machine Company, 5500 Tabor Road, Philadelphia 20, Pa. available on request.

•

Ion-Kote, a phosphatizing paint-preparatory wash for metal in process is manufactured by The DuBois Company, Cincinnati, Ohio. It is designed for cleaning metals in industrial spray washers prior to painting, and will deposit a hard, dust-free phosphate coating on metal which prevents rust and increases bond.

•

Synthetasine 100, a new epoxyl resin protective coating liner for steel containers is now available commercially from Synthetasine Protective Coatings, Inc., 600 Fifth Ave., New York. The material, developed at Battelle Memorial Institute, is resistant to alkalis, dilute mineral acids, chlorinated solvents, formaldehyde (36-38 percent aqueous), detergents, detergents combined with hydrocarbon solvents, fatty acids, emulsions. It combines flexibility with excellent resistance to normal abuse in shipping and moving, not shattering readily like pure phenolics. There are indications the white variety liner is inert and should impart no toxics to foods. A list of the products with which the material has been tested is available on request. Other tests are continuing. Synthetasine Protective Coatings, Inc. licensor, is owned by members of the Steel Shipping Container Institute, Inc. which created the research program responsible for its development. Licensees manufacturing it are Finishes Division of Interchemical Corp. and Stoner-Mudge, Inc. both of which will supply on request a leaflet describing the material.

•

Speedline Insert Flanges, manufactured by Horace T. Potts Co., Philadelphia 34, Pa. may be installed in flanges with an expanding tool and wrench, thus eliminating welding and subsequent annealing of sections of process lines. This type of flange is being used in the manufacture of organic esters.

•

Dix Engineering Co. Inc., 1415-17 Dix Road, Lincoln Park (Detroit) 26, Michigan is using fully automatic metallizing equipment designed and built for specific production applications by Metallisation, Ltd., Dudley, England, All ferrous and non-ferrous metals produced in wire form can be metallized to a wide variety of products including all metals, glass, wood, paper, ceramics, carbon and many plastic base materials. Costs for blasting and spraying in some instances are as low as 10 cents a square foot.

•

Phillips Vapor Degreasers are described in a bulletin issued by Phillips Manufacturing Co., 3475 Tuouhy Ave., Chicago 45, Ill.

•

Bakelite and Vinylite plastic components now can be plated with twelve different colors as well as natural metal finishes in a new process developed by Plastiplate Co., Inc., South River, N. J. The plastic parts first are sandblasted or wet or dry tumbled to rough the surface, then a bond coat of silver 100,000-inch thick is applied by chemical reduction, after which the part is plated in perforated barrels rotating in a copper salt solution. After the copper coating is complete, a thin finish coat of the gold, silver or other metal is applied. The parts are then mass polished

(Continued on Page 25)

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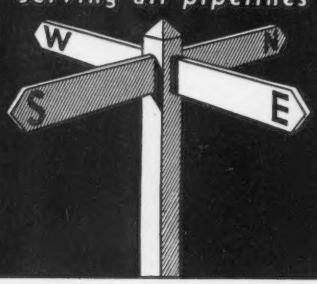

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New Products—

(Continued From Page 24)

in revolving barrels containing steel shot and soap solution.

•

Bulletin TA 1559 giving analyses and tables of physical and mechanical properties as well as application data for 20 popular carbon, alloy and stainless tubing steels is available from the Babcock & Wilcox Tube Co., Beaver Falls, Pa.

•

Tuffstuff, a rigid, corrosion resistant plastic piping has been added to the line of Clopay Corp., Cincinnati. The unplasticized polyvinyl chloride extrusions are being used successfully as replacements for copper, steel and wood processing equipment. It is supplied in standard pipe and tubing sizes.

•

Quick Reference to determine suitable coatings for rust prevention, chemical corrosion and dampness is possible by use of a new folder available from Wilbur & Williams Co., 130 Lincoln St., Brighton 35, Mass.

•

Solar Aircraft Co., 2200 Pacific Highway, San Diego 12, Cal. has issued a new catalog containing over 78,000 combinations of bellows type expansion joints. The 40-page catalog illustrates a diversified line of standard and special bellows assemblies from ½-inch pipe sizes to 72-inch pipe sizes covering a complete line of pressures from vacuum

(Continued on Page 26)

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New Products—

(Continued From Page 25)

to 1000 pounds. The bellows are made from stainless steel and various heat and corrosion resistant alloys. Free copies are available on request.

•

Metco Type 5E metallizing guns, with a companion Type 4E designed for machine element work, develop the highest spraying speeds yet available in guns for hand held operation, the manufacturers, Metallizing Engineering Co., Inc., 38-14 30th St., Long Island City, N. Y. claim. A patented jet siphon principle in the gas head automatically compensates for variations in gas pressure as high as 10 lb. and provides a steady unvarying flame. The new guns also have automatic control of wire feed. Type 5E, the first gun specifically designed for spraying softer metals, sprays 3/16-inch wire and will deposit as much as 55 lb. of zinc per hour, aluminum 15 lb. per hour. The guns weigh only 4 lb. 12 oz.

•

Corrosion Service Piping, Bulletin 485 of Taylor Forge & Pipe Works, P. O. Box 485, Chicago 90, Ill. gives in 34 pages design, size, specifications and corrosion resistance data on a wide range of piping. Copies are available on request.

•

Pittsburgh Chemicals, a new booklet issued by Pittsburgh Coke & Chemical Corp., Grant Building, Pittsburgh, Pa. summarizes the principal products of five of its divisions. The bulletin lists uses and applications of the products, and wherever possible, their specifications. Copies are available on request.

•

International Nickel Co., Inc. Technical Service Section, 67 Wall St., New York 5, N. Y. will supply on request copies of the following publications: "Fusion Welding of Nickel and High Nickel Alloys," Technical Bulletin T-2, 44 pages. This bulletin gives a wide range of information. "Engineering Properties and Applications of Ni-Resist," a 36-page bulletin describing eight types of austenitic nickel alloy cast irons. Applications and service data in many fields, photographs, tables of properties and corrosion data on nearly 400 conditions are covered. (Write to Dept. EZ)

NACE MEMBERS CHANGING STATUS

Notification to Central Office NACE of changes of membership status, including changes of address should be made *personally* by the member.

NACE is reluctant to make changes in membership records except *when asked to do so by members themselves.*

Please note also:

1. **Active and junior memberships are *non-transferable,* because applications are signed personally by members, therefore**
2. **All persons wishing to become members of NACE must submit and *sign personally* an application containing a concise statement of qualifications and including the names of two NACE members in good standing as references.**

Cogshall Is Recalled To Duty by U. S. Navy

James Cogshall, corrosion engineer for the Pennsylvania Salt Manufacturing Co., originally scheduled to be nominated for the chairmanship of Detroit Section, has been called back to active duty by the navy. Section members accepted his resignation with regret. Norman Kiersten, active during the organization phases of the section has assumed the office of chairman ex-officio of the executive committee.

Inter-Society Corrosion Committee Members

Representatives of NACE on the Inter-Society Corrosion Committee are George Seagren of Mellon Institute, Pittsburgh and C. M. Shigley of Dow Chemical Company, Freeport, Texas. They succeed F. L. LaQue and R. B. Mears. It was reported in error in *Corrosion* Mr. Seagren had succeeded both Mr. LaQue and Mr. Mears.

•

Technical Committees of NACE are formed when sufficient interest is evidenced and after approval by the chairman of the Technical Practices Committee and the association's governing board.

•

Reports of technical committees of the association are available for purchase by members and non-members.

Sessions of Corrosion Interest Scheduled at ASTM Meeting in June

Sessions of corrosion interest are included among the 35 proposed to be held by the American Society for Testing Materials at its 50th Anniversary meeting at New York City during the week of June 23, 1952. Groups of papers and symposia on the following subjects are likely to be of corrosion interest: fretting corrosion, continuous analysis of water, plastics, conditioning and weathering, fatigue, effect of temperature, and tin.

Symposium on Testing Metal Powders Is Set

A symposium on testing metal powders and metal powder products consisting of several technical papers by leading authorities will be the technical feature of the 1952 Spring Meeting of the American Society for Testing Materials to be held during the week of March 3 at Cleveland, Ohio.

Papers concerned with any phase of testing of the materials are invited. Information can be secured from F. V. Lenel, Secretary of ASTM Committee B-9, Rensselaer Polytechnic Institute, Troy, N. Y.

Hadley Resigns

Raymond F. Hadley, Susquehanna Pipe Line Co., Philadelphia, has resigned as chairman of TP-14, Instruments for Corrosion Measurements, bringing to two the number of technical practices committees without chairmen. The other committee is TP-13, Annual Losses Due to Corrosion.

De-Icing Salts Committee

F. E. Kulman of Consolidated Edison Co., New York, has been named chairman of TP-19 Corrosion by De-Icing Salts. The committee will investigate corrosion caused by street de-icing salts on metallic equipment above and below ground and will study and recommend mitigative measures.

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PERSONALS

James Reed has been made development engineer in service and product development department and **Roy Bostick** has been promoted to sales development engineer in the sales department at Tulsa; **Paul S. Clinkenbeard** and **Dale Benefield** have been named district sales engineer and sales engineer respectively at Shreveport by Dowell Incorporated. Six employees in the Edmondton, Canada office have been promoted: **William Stemp,** area development engineer; **Spence Lawrence,** office manager; **William Wedderburn** and **Lewis McCabe,** service supervisors and **A. E. Thorson** and **Wallace Thorvaldson,** sales engineers.

•

Dale Carroll has been added to the Houston district sales office of Taylor Forge & Pipe Works.

•

Fred R. Grassle, has been promoted to assistant to the president and **R. T. Kidde** has been appointed general sales manager of all divisions by Hills-McCanna Co., Chicago.

•

M. E. Holmberg has opened a consulting engineering office in the Bermac Building, 4101 San Jacinto, Houston. Mr. Holmberg for the past 15 years has been associated with Phillips Petroleum Corp., Bartlesville, Okla. where for 10 years he was manager of Phillips test division. He graduated in metallurgical engineering from Pennsylvania State College in 1931, and was employed successively by Aluminum Co. of America and Black, Sivalls and Bryson. He is the author of many technical papers on metallurgy.

•

James F. Eversole has been appointed manager of research administration of Union Carbide and Carbon Corp. He joined the research organization as a research chemist in 1929.

•

Harold C. O'Brien, Jr., president of Royston Laboratories, Inc., Blawnox, Pa. and **Robert S. Haverhill,** director of rubber research, St. Joseph Lead Co., Monaca, Pa. presented papers before the Institute of the Rubber Industry at London, England, September 28. Dr. O'Brien's paper dealt with the discovery of a relationship between the electrostatic surface contact potentials of organic, high molecular weight, dielectric plastomers and their tendency to oxidize. Mr. Haverhill's paper described a new electrostatic probe for measuring and recording the electric charge of a rubber batch during mixing in the Banbury mixer.

•

James S. Kone has been appointed sales representative for West Texas, the Panhandles of Oklahoma and Texas and Southwestern Kansas by T. D. Williamson, Inc. Tulsa. **James H. McBrien** and **Floyd E. Zongker** have been named service engineers. Both are experienced in installation and servicing of corrosion control equipment.

•

Bruce A. Williams has been named sales engineer for John A. Green Co. manufacturers representatives, Dallas, Texas.

(Continued on Page 28)

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PERSONALS

(Continued From Page 27)

William A. James has been appointed director of research and **Jerry Shaw** sales representative by Dearborn Chemical Co., Inc., Chicago. Dr. James will have charge of all research activities at the laboratories located at 2454 Dundas St., West, Toronto.

•

Hugh L. Hamilton, chairman of NACE's North East Region has been named to manage and direct the activities of the A. V. Smith Engineering Co., Inc., Bala Cynwyd, Pa. The company conducts field surveys and studies leading to recommendations for corrosion control. Mr. Hamilton had been with Atlantic Refining Company subsidiaries, the Keystone Pipe Line Company and the Buffalo Pipe Line Corp. for fifteen years. He is also a member of AIEE.

•

Lewis F. Scherer, formerly chief engineer of the Texas Pipe Line Company and its affiliates is now assistant general manager of the Texas Pipe Line Company and the Texas-New Mexico Pipe Line Company. He is in charge of all engineering and construction.

During Mr. Scherer's tenure as chief engineer his company was engaged in an extensive expansion program involving construction of several big inch pipe lines. He has been in charge of engineering on these projects, including corrosion problems.

Active in corrosion work since 1934, Mr. Scherer helped organize the Mid-Continent Protective Association, a predecessor of NACE. He was among the organizers of NACE and was first director of South Central Region, taking an active part in its formation and in organization of the Houston Section. In 1950 he was general chairman of the South Central Regional meeting.

Mr. Scherer holds a degree in mechanical engineering from University of Illinois. Joining Texas Pipe Line Company in 1928 as a designer, he became assistant chief engineer in 1932. In 1942 he was loaned to the War Emergency Pipe Line as a special assistant to the chief engineer in design and specifications and later became station construction superintendent and then chief engineer. He went to California in 1944 to take charge of construction of a pipe line for use of the United States Navy. At the end of the war he returned to Texas Pipe Line Company as chief engineer in 1945.

Succeeding Mr. Scherer as chief engineer for Texas Pipe Line Company is R. B. Trow, formerly Mr. Scherer's assistant in Houston. Mr. Trow becomes chief engineer of the Texas Pipe Line Company and the Texas-New Mexico Pipe Line Company. R. W. Phillips, Mr. Scherer's former assistant in Tulsa, becomes chief engineer of the Texas Empire and Kaw Pipe Line Companies.

•

E. Rowland English has been named vice-president in charge of sales and assistant general manager of Pipe Protection Service, Inc., Elizabeth, N. J. Mr. English is secretary-treasurer of North East Region.

•

C. A. Goldkamp, 62, electrolysis engineer for San Diego Gas and Electric Co. and formerly secretary of Western Region, NACE, died at his home in San Diego April 27. He had been employed by the utility company almost 40 years. He is survived by his widow, two sons and seven grandchildren. He was considered a top authority on electrolysis.

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Corrosion Abstracts

NATIONAL ASSOCIATION OF CORROSION ENGINEERS

Index to CORROSION ABSTRACTS

Vol. 7 November, 1951 No. 11

Page

2. TESTING

3. Laboratory Methods and Tests ... 223a

3. CORROSION TYPES AND INFLUENCING FACTORS

2. Types ... 223a
5. Factors Physical and Mechanical ... 224a
6. Factors Electrochemical ... 226a
7. Factors Metallurgical ... 226a

4. CORROSIVE ENVIRONMENTS

3. Chemicals Inorganic ... 230a
4. Chemicals Organic ... 230a
5. Soil ... 232a
6. Water and Steam ... 232a

5. PREVENTIVE MEASURES

2. Cathodic Protection ... 236a
3. Metallic Coatings ... 236a
4. Non-Metallic Coatings and Paint ... 240a
8. Inhibitors and Passivators ... 242a

6. MATERIALS OF CONSTRUCTION

2. Ferrous Metals and Alloys ... 242a
3. Non-Ferrous Metals and Alloys, Heavy ... 242a
4. Non-Ferrous Metals and Alloys—Light ... 243a

(Complete Topical Index used for Corrosion Abstracts may be found in FIVE YEAR INDEX TO TECHNICAL ARTICLES, Corrosion, December, 1950.)

*** PAGINATION OF CORROSION ABSTRACTS**

Two numbers appear on each page of Corrosion Abstracts. The number in the upper outer corner is for page sequence within the issue only. The number in the lower outer corner, which is followed by the letter "a," denoting "abstracts," is for the convenience of those who bind Corrosion Abstracts by volumes. Because both numbers appear on each page and because it is believed indexing by the volume serial number will be more useful, the "Index to Corrosion Abstracts" is keyed to the number in the lower outer corner of each page followed by the letter "a."

TESTING

• Laboratory Methods and Tests

2.3, 7.7

Weathering Studies on Polyethylene for Wire and Cable Applications. V. T. Wallder, W. T. Clarke, J. B. De Coste and J. B. Howard. *Am. Paint J.*, **34**, No. 32, 79 (1950).—RPI.

CORROSION TYPES & INFLUENCING FACTORS

• Types

3.2

Aluminum-Vinyl "Cold Solder" Has Interesting Possibilities for Industry. Edwin Laird Cady. *Mat. & Meth.*, **30**, No. 4, 77-79 (1949) Oct.

Aluminum-vinyl cold solder has been used to repair sheet metal, pistons, weldments, castings and water pipes and tanks having pitted or otherwise defective surfaces. The solder adheres well to clean surfaces and is resistant to a prolonged 400 degree-500 degree F temperature. It is readily filed or sanded but cannot be cut with a knife and does not corrode in water or water vapor. A film 1/32-in. thick can be bent over a 4-inch mandrel without cracking.

A typical formulation contains 60 percent atomized aluminum powder, 10 percent vinyl resin and 30 percent acetone. It is applied as a paste to a clean surface with a spatula or any similar tool. A 1/32-in. film of solder dries in ½ hour, but a 1/16-in. film requires 5-6 hours; thick coats may be applied in increments if time is limited.—PDA.

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NACE will NOT accept orders for photoprint or microfilm copies of material not published by the association.

PRIMARY SOURCES OF ABSTRACTS PUBLISHED IN CORROSION

AER—Aeronautical Engineering Review, Institute of Aeronautical Sciences, Inc. 2 East 64th St., New York 21, N. Y.

ALL—The Abstract Bulletin, Aluminum Laboratories, Ltd. P. O. Box 84, Kingston, Onatrio, Canada.

AWWA—Journal, American Water Works Association. Amer. Water Works Assoc., 521 Fifth Ave., New York 17, N. Y.

BL—Current Technical Literature, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

BLR—Battelle Library Review, Battelle Memorial Institute Library. 505 King Ave., Columbus, Ohio.

BNF—Bulletin; British Non-Ferrous Metals Research Association. 81-91 Euston St., London NW 1, England.

CALCO—Calco Chemical Division, American Cyanamid Corp. Bound Brook, New Jersey.

CE—Chemical Engineering, McGraw Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

CEC—Consolidated Edison Co. of New York, Inc. 4 Irving Place, New York 3, New York.

EL—Electroplating. 83/85 Udney Park Road, Teddington, Middlesex, England.

EW—Electrical World, McGraw-Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

GPC—General Petroleum Corp. of California. 2525 East 37th St., Los Angeles 11, Calif.

INCO—The International Nickel Co., Inc. 67 Wall Street, New York 5, New York.

IP—Institute of Petroleum. 26 Portland Place, London W#1, England.

MA—Metallurgical Abstracts, Institute of Metals, London, England. 4 Grosvenor Gardens, London SW 1, England.

MI—Metallurgia Italiana. Associazone Italiana di Metallurgia. Via S. Paola, 10, Milano, Italia.

MR—Metals Review, American Society of Metals. 7301 Euclid Ave., Cleveland 3, Ohio.

NALCO—National Aluminate Corp. 6216 West 66th Place, Chicago 38, Illinois.

NBS—National Bureau of Standards. Supt. of Documents, U. S. Gov't Printing Office, Washington 25, D. C.

PDA—Prevention Deterioration Abstracts. National Research Council, 2101 Constitution Ave., Washington 25, D. C.

RA—Refrigeration Abstracts, American Society of Refrigeration Engineers. 40 West 40th St., New York 18, N. Y.

RM—Revue de Metallurgie, Paris, France. 5 Cite Pigalle, Paris (9e), France.

RPI—Review of Current Literature Relating to the Paint, Colour, Varnish and Allied Industries, Research Association of British Paint, Colour & Varnish Manufacturers, London. Waldegrave Rd., Teddington, Middlesex.

TDD—Technical Data Digest, Air Material Command—Technical Service Section, Central Air Documents Office, Wright-Patterson Air Force Base, Dayton, Ohio.

TIME—Transactions of Institute of Marine Engineers. 85 The Minories, London EC 3, England.

UOP—Universal Oil Products. 310 South Michigan Ave., Chicago, Illinois.

ZDA—Zinc Development Association. Lincoln House, Turl Street, Oxford, England.

3.2

Theory of the Oxidation of Metals. N. Cabrera and N. F. Mott. *Reports on Progress in Physics,* **12,** 163-184 (1949).

Presents a general theoretical explanation of the above based on recent theoretical and experimental work. Deals with the formation of stable films at low temperature, the region of intermediate temperatures, the parabolic law and adhesion and crystal form of an oxide film. 28 references.—BLR.

• Factors Physical and Mechanical

3.5, 5.3

The Effect of Heat on Electro-deposited Chromium. R. Graham, K. R. Williams and R. W. Wilson. *Engineering,* **167,** 241-243; 265-267 (1949) Mar. 18, Mar. 25.

The object of this investigation, which was carried out at the Thornton Research Centre of the Shell Refining and Marketing Co., was to examine the effect of heat and friction on the physical properties of electro-deposited chromium in the temperature range from 100 degrees to 450 degrees C and to find, if possible, the factors, other than poor adhesion to the basis metal, responsible for those cases in which satisfactory wear resistance is not obtained. It is suggested that hydrogen is the operative factor in the wear of chromium at elevated temperatures. It follows from this that trouble may be experienced down to 80 degrees C, where hydrogen is first evolved, but would be longer in developing. This is borne out by crack formation being found at 250 degrees C, but pronounced at 300 degrees C, and also by scoring being found in wear tests at 100 degrees C after six hours but not after one hour. If the suggestions made above concerning the wear of chromium are correct, then it should be possible to overcome the difficulties by adopting a definite procedure of heating and grinding combined with reverse-current etching.—TIME.

3.5, 2.3

Erosion-Corrosion of Metals and Alloys [Cupro-Nickel, Lead, and Steels]. M. G. Fontana and W. A. Luce. *Corrosion,* **5,** No. 6, 189-193 (1949).

The mechanism of erosion-corrosion is briefly described, the details are presented of an apparatus for studying the phenomenon. The results are given of tests on steel, cupro-nickel and lead. It is claimed that the apparatus is considerably more reliable than ordinary conventional test methods for predicting the performance of actual equipment and that the results obtained correlate well with those obtained in service. It is shown that, using synthetic sea-water, a 70:30 cupro-nickel with a 0.59 percent iron content had appreciably better resistance to this type of attack than one containing only 0.12 percent iron. In some of the tests the penetration amounted to 0.039-in. per year in the latter case and only 0.011-in. per year in the former. Tests showed that tapwater containing a wetting agent at a temperature of 95° C is extremely destructive to lead. With a lead alloy containing 8 percent antimony, the erosion-corrosion effect in sulfuric acid was at a maximum when the concentration of the acid was about 25 percent. In 10 percent sulfuric acid increase in temperature is shown to increase the rate of attack. It is also shown that contact of stainless steel with lead under erosion-corrosion conditions, greatly increases the corrosion rate on the former on account of the galvanic relationship between the two metals. 6 references are appended.—MA.

3.5

Evaluation of the Effects of Rust on Sheet Steel. (In Italian.) V. Montoro and G. Canesi. *Met. ital.,* **41,** 225-228 (1949) Sept.-Oct.

Presents results of study of a method devised for determination of effects of rust on mechanical properties. Correlates decrease in the latter with decrease in thickness of unoxidized steel.—MA.

3.5, 6.2, 3.4, 2.3

Stress Corrosion Cracking of Stainless Steels. I. Practical Experiences. II. An Investigation of the Suitability of the U-Bend Specimen. (In Swedish.) Helmer Nathorst. *Jernkontorets Annaler,* **134,** No. 3, 97-133 (1950).

Part I presents a summary of service failures due to the above which have been reported in Sweden. The cases are divided into three groups on the basis of corroding liquid: The first containing chlorides, the second alkalies and the third miscellaneous agents. Among the latter are sodium hypochlorite, o-dichlorobenzene, and pine resin. Different cases mentioned in the literature are also described. Typical corroded sections are illustrated. In Part II, reproducibility of U-bend tests using 1.5 mm specimens of 18-8 sheet immersed in hot concentrated calcium chloride solutions was investigated. It was found that fairly good reproducibility can be achieved if certain precautions are followed. Drawbacks of the test are pointed out. 33 ref.—BLR.

3.5, 1.3

The Influence of Stress on Corrosion, Part 1. J. J. Harwood. *Corrosion,* **6,** No. 8, 249-259 (1950) Aug.

The effects of stress on the internal structure and energy characteristics of metals are discussed with relationship to their influence on corrosion reactions. The nature and importance of residual stresses and the nonhomogeneity of worked metals are emphasized. Recent concepts of the nature of grain boundaries are reviewed and their importance in reactions where stress and corrosion act in a conjoint manner is described. There are several ways in which the stresses may influence the nature, rate, and distribution of corrosion reaction; i.e., by increasing the internal energy level of the metal system and causing a possible shift of electrochemical potential in a more active direction; by causing an intrinsic increase in the rate of corrosion; by damaging protective surface films; by influencing polarization reactions; by changing the metallurgical characteristics of the metal system in promoting phase transformations, precipitations, etc. and by accelerating the rate of corrosion by purely mechanical effects. Most serious effects of stress are in localized corrosion phenomena, such as stress-corrosion and corrosion fatigue. Stress-corrosion of alloys is discussed and in the influence of metal composition and structure, environment, state and energy of stress is outlined. The oxide film, mechanical and electrochemical theories of stress-corrosion cracking are reviewed and it is shown that the experimental evidence favors an electrochemical mechanism.—TDD.

3.5

Erosion Due to Dust Particles in a Gas Stream. R. L. Stoker, University of California, Los Angeles. *Ind. Eng. Chem.,* **41,** 1196-1199 (1949) June.

Results of limited experiments made to evaluate erosion factors that can arise in high velocity, gas-solid flow systems and, in particular, in fluid type catalytic cracking plants, indicate that the erosion resistance of more durable materials may be predicted by sandblasting plaster models.

Black iron and gypsum plaster were used as target materials. The dusts were a fairly fine silica sand and two grades of a commercial synthetic catalyst of the type used in cracking plants. The air velocity was varied from approximately 100 to 600 ft per sec. for the iron and about 60 to 150 ft per sec. for the plaster targets. Several angles of impingement were tried on the black iron. Erosion was measured by the change in weight of the specimen per 500 g of dust.—PDA.

3.5, 4.6

Some Cavitation Phenomena. T. S. Wylie. *J. Roy. Tech. Coll., Glasgow,* **5,** No. 1, 6-25 (1950) Jan.

Study of cavitation in water subjected to sound waves of 3780 cycles per sec., and of cavitation erosion in solid metals and in copper and tin foil and its variation with time.—BNF.

3.5, 6.4, 3.7

Stress Corrosion of Light Metals. (In Dutch). A. Hartman. *Metalen,* **4,** 21-27, 39-47, 59-65 (1949) Oct., Nov., Dec.

Discusses the principal theoretical and experimental investigations on aluminum and magnesium alloys reported in the literature. Testing methods; influence of alloying elements and of heat treatment. Nov. issue: Effects of different corrosive media on structural factors such as notches, of temperature, of crystal structure, of type of stress and of heat treatment. Concluding installment: Theory of stress corrosion and its application to specific types of aluminum alloys. 52 ref.—MR.

3.5, 6.4, 2.3

Stress-Corrosion of Wrought Magnesium-Base Alloys. Hugh L. Logan and Harold Hessing. *J. Res. NBS.* **44,** No. 3, 233-234 (1950).

Stress-corrosion tests were carried out on annealed and hardended magnesium 1.5% manganese alloy, magnesium-aluminum-zinc alloys containing 3-8% aluminum, magnesium-3% aluminum-1% zinc alloy clad with magnesium-1-5% manganese alloy and magnesium-5.7% zinc-0.6% zirconium alloy. Tests were made under atmospheric exposure, by continuous immersion in a sodium chloride + potassium chromate solution and by intermittent immersion in a 0.01% sodium chloride solution. The material most resistant to stress-corrosion was found to be the clad magnesium-3% aluminum-1% zinc alloy, this being followed by the magnesium-5.7% zinc-0.6% zirconium alloy which was found to be susceptible to stress-corrosion only at stresses >20,000 lb. per sq. in. The bare magnesium-1.5% manganese alloy was resistant to stress-corrosion up to stresses of 16,000 lb. per sq. in., while all the magnesium-aluminum-zinc alloys

were found to be susceptible to stress-corrosion, the susceptibility increasing with aluminum content up to 6.5%. The decrease in tensile properties of unstressed specimens exposed to the atmosphere was small. Results obtained using the intermittent-immersion test with 0.01 sodium chloride solution gave better correlation with the atmospheric-exposure tests than did the continuous-immersion tests in the sodium chloride + potassium chromate solution.—MA.

3.5

Corrosion Fatigue as an Intracrystalline Effect. (In German). Franz Lihl. *Metall.*, **4**, 130-131 (1950) Apr.

X-ray studies showed that the etching of ingot iron with acid results in formation of surface stresses which can be relieved, but not eliminated, by extended annealing followed by slow cooling. Mechanism of the above is explained on the basis of test results.—BLR.

3.5, 6.6, 5.4

Troublesome Bubbles. *Chem. Eng. News*, 28, No. 19, 1544 (1950) May 8.

When cavitation takes place, it is the vapor-filled not the air-filled bubble that does the explosive damage, where turbulence occurs in fast-flowing water. In fact, it is not the bubble but its rapid condensation that erodes high quality concrete and steel pipe in a relatively short time. Resulting pressures are estimated at 10,000-100,000 psi. To correct this fatigue type of failure the Bureau of Reclamation has found that a 1-inch thick rubber plate firmly bonded to concrete is sufficient cushioning to prevent cavitation in 50-hour tests. When air bubbles are introduced into the water which contains vapor-filled bubbles, the former help cushion the explosion of the latter. Tests are now being made to determine the feasibility of using these anticavitation methods in the field.—INCO.

3.5,

Potentials Set Up by Thermal Gradients in Iron Immersed in Sodium Chloride Solutions. H. H. Uhlig and O. F. Noss, Jr. Paper before NACE, 6th Ann. Mtg. St. Louis, Apr. 4-7 (1950). *Corrosion*, **6**, No. 5, 140-143 (1950) May.

The relative damage caused by galvanically coupling a piece of iron at high temperature to a piece at low temperature in an electrolyte is of importance in condenser tubes, boiler tubes, radiators, stills, etc. The potential of carbon steel at 100°C vs. steel at 25°C in 3% sodium chloride under specific conditions of aeration and stirring is 0.024 volts, with the hot electrode as anode. Decrease of aeration or stirring, or more dilute solutions of sodium chloride decrease the potential difference. The short circuit current is aerated, stirred 3% sodium chloride for a 75°C temperature differential in the particular cell amounted to 0.00043 amp. sq. in. or the equivalent of the corrosion rate of 0.03 ipy. In nitrogen saturated solutions, this current falls to zero. This current is limited by polarization of the cathode rather than resistance of the electroylte (0.125-3% sodium chloride). It appears that the hot iron electrode, as sacrificial electrode, will cathodically protect cold steel to which it is coupled in sodium chloride solution. Charts. 7 References. —INCO.

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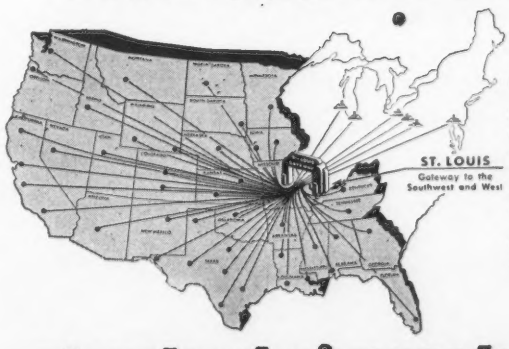

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3.5, 6.3, 3.7, 2.3

Stress Corrosion of Brass. (In Dutch) W. G. R. de Jager. *Metalen*, **4**, 138-148, 185-190 (1950) Mar., May.

Surveys current literature on the stress-corrosion cracking (season-cracking) problem of brass. Standardization of an accelerated ammonia test to control susceptibility to this type of cracking of brass is recommended. May issue describes the stress-corrosion resistance of brasses containing various amounts of zinc, phosphorous, arsenic, antimony, silicon, nickel and aluminum. 30 references.—BLR.

3.5

The Abrasion Resistance of Metals. R. D. Haworth, Jr. *Trans. ASM*, **41**, 819-860 (1949).

• Factors Electrochemical

3.6, 4.5

Detection and Measurement of Currents Other Than Stray Currents, Including Magnetic Earth Currents. Lyle R. Sheppard. Symposium on Cathodic Protection. Electrochem Soc. and NACE, 57-65 (1949).

Practically all underground metallic corrosion is indicated by the generation and flow of an electric current which may be caused by electrochemical cells, thermocouples, metal stress differences, changes in magnetic fields and microbiological action. These currents are best detected and determined by calculation from potential-difference and resistance measurements and certain proved circuits which have been developed for these measurements are described. 24 references are appended.—MA.

• Factors Metallurgical

3.7, 6.4

The Corrosion of Impure Aluminum, I. Effect of Iron, Silicon and Copper; II. Effect of Magnesium, Antimony and Silicon. Obinata and S. Nishikawa. *J. Inst. Metals*, Japan, **13**, 7-11, (1949) Aug.; *Metals Rev.*, **23**, No. 4, 38 (1950) Apr.

I: There is a decrease in weight, tensile strength and elongation of aluminum containing varying amounts of iron, silicon, and copper, upon immersion in 3 percent sodium chloride and 0.5 N hydrochloric acid. In general the effect of copper is the most harmful, followed by iron and silicon. II: Varying amounts of magnesium, manganese, antimony and silicon were added to 98 percent aluminum containing 1.2 percent iron, and 0.8 percent silicon to improve corrosion resistance in the same media, and also in 0.5 N sodium hydroxide.—ALL.

3.7, 6.5

How to Weld Corrosion Resistant Materials. W. G. Scherer. *Mat. & Meth.*, **32**, 60-61 (1950) Aug.

Describes recommended procedures for nickel and nickel-clad steels, stainless steels, nickel alloys, and copper alloys. By their use, welds that are no more susceptible to corrosion than unwelded areas can be made in most corrosion-resistant materials.—BLR.

3.7, 6.2

Corrosive Behavior of Copper-Alloyed Steels and Wulff and Uhlig's Passivity Theory. (In German) K. Werny, R. Eschelbach. *Werkstoffe u Korrosion*, 1, 16-20 (1950) Jan.

Short review. The small amount of copper (0.2-0.3 percent) required for maximum corrosion resistance indicates the formation of ionic solutions between copper and iron, with copper and copper oxide forming protective films around the cathodic iron. According to Wulff and Uhlig's thoery, the amount of copper required for maximum protection would be 3.1 percent. Includes graphs, drawings and photomicrographs. Tests of copper-bearing steels (atmospheric, water, waste gases and various acids) were made. Fields of application for the copper-bearing steels are given.—BLR.

3.7, 6.2

Investigations Into Corrosion-Resisting Cast Chromium-Nickel Steel With Special Reference to the Sigma Phase. *Metallurgia*, **41**, 163-164 (1950) Jan. From *Sulzer Technical Rev.*, No. 2, 1-8 (1949).

Deals with the influence of heat treatment on the formation of the above for type 20-14-4 (AISI 317). Data are tabulated.—BLR.

3.7, 3.6

The Influence of Stress Upon the Electrode Potential and Polarization of Iron and Steel in Acid Solution. M. T. Simnad and U. R. Evans. *Trans. Faraday Soc.*, **46**, 175-186 (1950) Mar.

Experimental results show that in acid solution, where no oxide film can survive, the unpolarized potential of cold-

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226a

worked iron and steel is anodic in relation to the same material in the annealed condition. The same difference was observed in experiments where a cathodic current was applied; at any given current density, potential of annealed specimens is about 25 mv nobler than that of the cold-rolled material. Corrosion rate is affected by dissolved oxygen and by previous surface treatment. 25 ref.—BLR.

3.7, 1.3, 1.7

Report of the Commission on Boron Steels of the ISRID. I. Literature Review of Foreign Work on Steels Containing Very Small Amounts of Boron. (In French) *Rev. Met.*, **46**, 859-868 (1949) Dec.

Contains a number of graphs derived from the literature. Effects of boron on various physical, mechanical, chemical, structural and workability characteristics are surveyed. 35 ref.—BLR.

3.7

Contribution on the Nature of Passivity in Stainless Steels. Henry Paige. Massachusetts Institute of Technology, Corrosion Laboratory, Technical Report 3. U. S. Office of Naval Research Contract N5ori-78-031-187 (1949) Oct.

Further evidence has been accumulated to show that passivity in stainless steels is accompanied by absorbed films. Quantitative measurements of oxygen consumption by 18-8 stainless steel specimens pickled with a sulfuric-hydrochloric acid mixture indicate that interstitial and absorbed hydrogen driven into the metal by the pickling process react with part of the oxygen. The remainder of the oxygen is presumably accounted for by formation of an oxygen monolayer. It is significant that not enough oxygen is consumed to establish a continuous multilayer oxide film.

Pickling with a hydrofluoric-nitric acid mixture, although it produces an active potential in 18-8 steel, is not followed by a similar oxygen consumption, indicating that passivity is produced by adsorption of nitrate ions in lieu of oxygen.

Potentials were measured on electrodes made of commercial 18-8 stainless steel sheet containing 0.045 percent carbon, polished with emery paper, and cleansed in boiling benzene and acetone. Surface treatments studied included 1. an oxidizing pickle in 10 percent hydrofluoric—15 percent nitric acid at 80 C for 10 min; 2. a nonoxidizing pickle in 25 percent sulfuric—25 percent hydrochloric acid at 90 C for 10 min, with a few drops of phosphorous in carbon disulfide added to increase hydrogen absorption; and 3. electropolishing in 42 percent glycerol—47 percent phosphoric acid at 0.15 amp per sq cm at 110 C for 15 min, all followed by a short rinse in distilled water. Periodic readings of galvanic potential in distilled water were taken using a silver chloride electrode as reference.—PDA.

3.7, 5.8

A Unified Mechanism of Passivity and Inhibition. II. R. B. Mears and R. H. Brown. *J. Electrochem. Soc.*, **97**, No. 3, 75-82 (1950). Cf. *Met. Abs.*, **16**, 572 (1949).

The inhibiting action of sodium chromate on the localized corrosion of aluminum exposed to a sodium chloride

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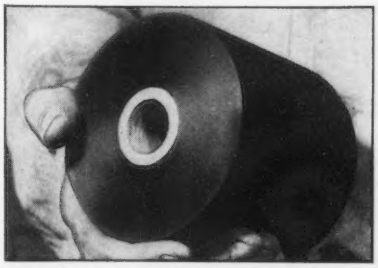

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solution is mainly the result of the polarization of local anodes and but for the fact that it depolarizes the local cathodes, sodium chromate would be an even more effective inhibitor. Addition of ferric chloride to a sodium chloride solution stimulates the localized corrosion of 18:8 stainless steel because it acts as a cathodic depolarizer and is practically without effect on the polarization characteristics of local anodes. In both these examples, the apparent single potential of the specimen moves in the cathodic direction so that the change of such a potential is of little value in itself in studying the mechanism of inhibitor action. Similarly, polarization curves obtained by the use of currents from an external source do not directly indicate the mechanism of inhibitor action. Two indirect methods of measuring the polarization curves are described, the "potential break" method and the "equivalent corrosion method." Both methods are limited by the assumption that the areas of the local anodes and cathodes are not altered by the application of external current. Additional methods are needed. It is indicated that polarization plays an important part in the measurement of potentials commonly accepted as reversible. Local cell reactions are probably occurring even in those cases where measured single-potential values agree with those calculated from thermodynamic data. Such correspondence will only be obtained when there is a specific type of local cell action. 5 references are appended.—MA.

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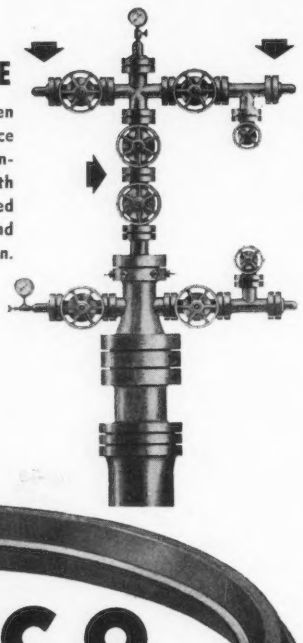

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3.7

Passivation of Metals. Rudolph Speiser and others. *J. Chem. Phys.*, **18**, 772-773 (1950) May.

Presents theoretical explanation of above phenomenon.—BLR.

3.7

Metal-Monolayer Interactions in Aqueous Systems. Part I. The Interaction of Monolayers of Long-Chain Polar Compounds With Metal Ions in the Underlying Solution. Part II. The Adsorption of Long-Chain Compounds From Aqueous Solution on to Evaporated Metal Films. G. A. Wolstenholme and J. H. Schulman. *Trans. Faraday Soc.*, **46**, 475-497 (1950) June.

In Part I, effects on mechanical properties of myristic acid monolayers, produced by the presence of salts of iron, aluminum, copper, cobalt, manganese, calcium and magnesium in the underlying solution were investigated. In Part II, evaporated films of copper and silver on hydrophilic surfaces were immersed in aqueous solutions of surface-active long-chain compounds and contact angles with these solutions measured under controlled conditions. Results are graphed, tabulated and discussed. 34 ref.—BLR.

3.7, 3.5

The Properties of Metallic Materials at Low Temperatures. P. Litherland Teed. Monographs on Metallic Materials published under the authority of the Royal Aeronautical Society. I., vii + 232 (1950). Chapman and Hall, Ltd., London. (21s. net.)

The properties of metals at temperatures below atmospheric have been investigated for a number of years, but except for the concise surveys made in America, a detailed examination of the published work has not been generally available.

The Royal Aeronautical Society Monograph on this subject can be said unhesitatingly to fill a real gap. This book is extremely useful, containing as it does, in tabular form, a very large number of data for all the more common metals and alloys, together with a full bibliography.

It may be that more attention is given to the materials and to the temperature range of interest to aircraft designers than might be demanded for a general text-book: materials were in use, for example in low-temperature gas-separation plant, for many years before high-altitude flying was a reality, and temperatures within a few degrees of absolute zero became of more than academic interest.

The volume opens with two short chapters on the general mechanical properties affected by temperature and then details in successive chapters the information available on aluminum alloys and on steels and ferrous alloys. It is natural that the question of notch brittleness should be dealt with at length in view of its importance, particularly in mild steels and two chapters describe the tests and information available, both for carbon steels and alloy steels. The next three chapters are respectively on magnesium and its alloys, copper and copper alloys and a miscellaneous collection of metals including zinc, tin and lead.

Points out that much of the previous work has been rendered of little value because the physical and chemical char-

acteristics of the materials tested have not been sufficiently defined. Lists the lines of research which would be most useful to follow, but list is by no means complete. The fact that some metals and alloys are susceptible to notch brittleness would suggest that examination of the yield stress/strain relationship under complex stress conditions at low temperatures would be far more revealing and useful than the "ultimate shear strength" mentioned by the author—a property which is very little used by the engineer.

The author has written a useful book in an easy and attractive style, and the publishers have produced it in clear print on good paper—two qualities of great importance in a reference volume such as this.—MA.

3.7, 5.8

Mechanism of Action of Chromates During Corrosion of Plain and Stainless Steels in a Liquid Medium. (In French) L. Cavallaro, A. Indelli and A. Tani. *Rev. Met.*, **46,** 818-820; discussion, 820 (1949) Dec.

Mechanism of chromate inhibition was investigated. Results indicate that it is caused by intensification of the "barrier" effect due to "electrochemical inertia" of the transition metals. Data are tabulated and charted.—BLR.

3.7, 5.8, 2.3

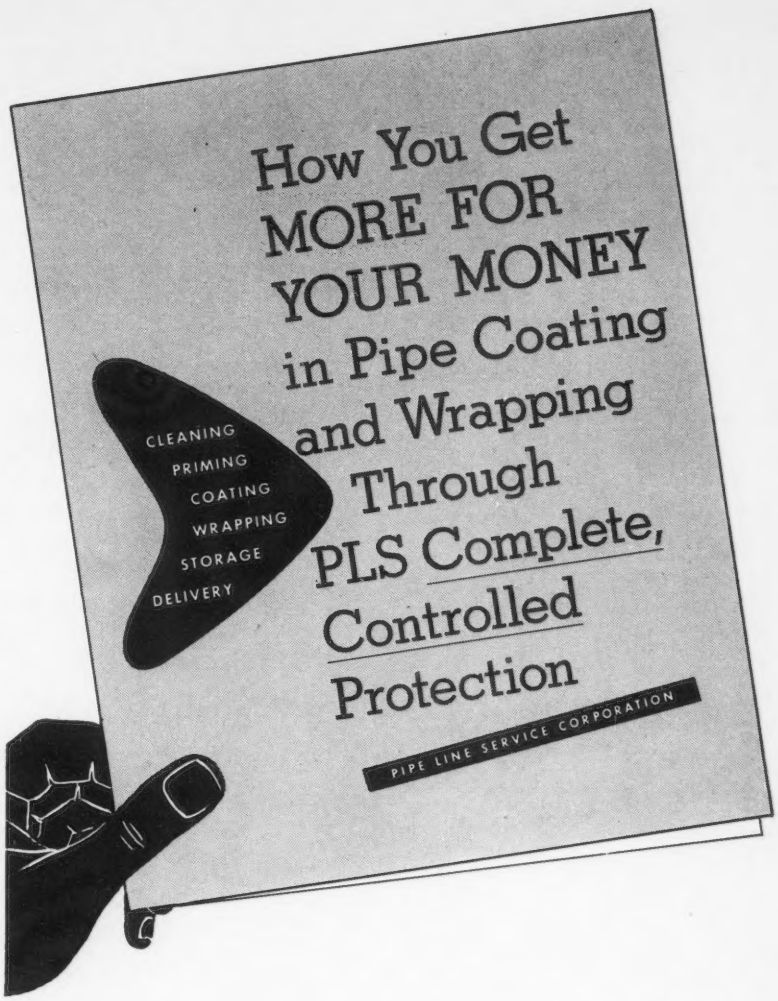
Orientation of a Polyfunctional Organic Molecule at a Steel Surface. Norman Hackerman and E. E. Glenn, Jr. *J. Phys. Colloid Chem.*, **54,** 497-505 (1950) Apr.

Describes electron-diffraction, surface-reflection investigation of the adsorption-desorption characteristics of a commercial corrosion inhibitor. It was found that adsorption of this inhibitor was more firm from the more dilute solutions within the range studied. Gradual fading of the arc pattern was noted. A possible mechanism for the phenomena observed is presented. 10 ref.—BLR.

3.7, 5.8, 3.6

The Effect of Amines on the Electrode Potential of Mild Steel in Tap Water and Acid Solutions. N. Hackerman and J. D. Sudbury. *J. Electrochem. Soc.*, **97,** No. 4, 109-116 (1950) Apr.

Potentials of SAE 1020 steel were measured in 1.0 N sulfuric acid and tap water, each with added amines. The steady state potential was found to be a function of the nature and concentration of the amine additives. The effect could not be completely reversed in all cases when the metal was placed in amine-free solutions. Anodic and cathodic polarization measurements in the presence of the amines showed that both anodic and cathodic areas were affected by the inhibitor. It is postulated that the measured changes are due to the adsorption of the polar compounds on the metal surface. The lack of complete reversibility is attributed to the heterogeneity of the surface giving rise to a variety of adsorption energies. Inhibition at the anodic area is due to an actual reduction in tendency for the iron ions to go into solution due to a displacement of electrons from the metal toward the positively charged particle rather than toward the cathodic areas within the metal. The amines may act as inhibitors at the cathodic areas because of diffusion effects, increased resistance, and over-voltage. 19 references.—INCO.



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3.7, 5.8, 6.4

A Kinetic Study of Organic Inhibitors of the Reaction Between Magnesium and Acids. R. Hurst and M. A. Jermyn. *J. Chem. Soc.*, 158-162 (1950) Jan.

Extends to the above system previous observations by other authors of the inhibition of metal-acid reactions by organic substances and presents simplified methods for studying the kinetics of such inhibitions. Dissolution of magnesium by acids was found to be inhibited by organic amines. Various reaction-rate constants were determined. The relation between inhibitor concentration and degree of inhibition was found to be that expected for an adsorption process. Effectiveness of the inhibitor depends on steric factors—shape and size of its molecule regarded as adsorbed on the metal surface at an active point.—BLR.

3.7

The Passivity of Metals. Part X. The Mechanism of Direct Dissolution of Ferric Oxide. M. J. Pryor and U. R. Evans. *J. Chem. Soc.*, **1949**, 3330-3336, Dec.

Alpha-ferric oxide was found to dissolve comparatively rapidly in hydrofluoric or concentrated hydrochloric acid, which readily formed soluble complexes with ferric ions. In dilute solutions of hydrochloric acid, sulfuric acid or perchloric acid, rate of dissolution falls off with time and the resulting solutions contain ferrous iron. Mechanisms are suggested.—BLR.

3.7

Technical Protection Against Corrosion. Walter Krannich, Herausgegeben von. Handbuch fur Vinidur und Oppanol. 2 Auflage. 23 x 16 cm. Pp. 407, with 231 illutrations. 1949. Munich: Carl Hanser. (DM 29)

CORROSIVE ENVIRONMENTS

• Chemicals Inorganic

4.3, 6.4

The Effect of Lead Bromide on Aluminum Alloys. R. Graham. *Shell Aviation News*, No. 144, 1821 (1950) June. *Tec. Data Dig.*, **15**, No. 9, 46 (1950) Sept. *Light Metals Bull.*, **12**, 585 (1950) July 21.

Tests are described which indicate that corrosion of aluminum alloys is due to the bromide radical. Presence of water inhibits the corrision. Problems of piston corrosion and engine operation are discussed.

4.3, 6.2, 3.4, 2.3

Concerning Corrosion Resistance of Chromium-Nickel Stainless Steels to Commercial Sulfuric Acid. (In French) J. M. Defranoux. *Rev. Met.*, **47**, 447-453; discussion, p. 454, (1950) June.

Results of experiments indicate the existence of a "passive" state, however the rate of corrosion in this state is still appreciable. Resistance to corrosion of 18-8 stainless containing 2.5 percent molybdenum depends to a considerable extent on the presence of impurities in the sulfuric acid. Intentional addition of certain substances in small amounts, especially nitrate ion, nitrogen trioxide, ferric ion and arsenious ion makes it poscontact with commercial sulfuric acid. —BLR.

4.3, 5.8, 6.2

The Solubility of Iron in Hydrochloric Acid During the First Few Seconds. (In German) K. Wickert, E. Bohnert and H. Pilz. *Werkstoffe u Korrosion*, **1**, 106-107 (1950) Mar.

Object of the study was to determine effects of an inhibitor (hexamethylenetetramine) on the above. Data are tabulated.—BLR.

4.3, 1.2, 1.6, 8.8

Acid Handling: The Transport and Handling of Sulfuric and Hydrofluoric Acids. Published by the Imperial Smelting Corporation, Ltd., at Avonmouth, Bristol. 68 pp. (1950) 10s. 6d.

This publication, incorporating much practical experience, will be of great value to all concerned with these acids. There are chapters on materials of construction, storage, transport in containers, pipe lines, valves and cocks, pumps, accident prevention and anhydrous hydrofluoric acid.—BNF.

4.3, 6.5, 3.4, 3.5

Corrosion. Mars G. Fontana. *Ind. Eng. Chem.*, **42**, 69A-70A (1950) Aug.

Discusses selection of materials of construction for contact with various concentrations of hydrochloric acid under various conditions of temperature, aeration, presence of other materials, etc.—BLR.

4.3, 6.2, 6.3, 2.3

Corrosion Resisting Cast Alloys Containing Nickel, Chromium and Molybdenum. M. M. Hallett. Paper before Soc. Chem. Ind., Chem. Eng. Group, London (1950) Apr. 25. *Chemistry & Industry*, No. 21, 406 (1950) May 27.

A detailed account of the behavior of 6 cast alloys under corrosion tests with hydrochloric acid, sulfuric acid, and nitric acid. Results of a number of tests were shown graphically and indicated that for nitric acid good service is given by 33 chromium cast iron or 18-8 nickel-chromium stainless steels under all conditions except that of boiling strong acid. For resistance to sulfuric acid at low temperature Ni resist is satisfactory while molybdenum bearing stainless steel is best for dilute acid and Corrosist B (67.76 nickel-30.2 molybdenum) is best for hot acid except when acid is boiling and strong, for which Corrosist D (a nickel base alloy with about 10 silicon) should be used. Corrosist C (60 nickel-15 chromium-18 molybdenum) may be used for sulfuric acid at low temperatures when abnormally low rates of corrosion are needed.—INCO.

4.3, 3.6, 5.8, 3.4

The Rate of Corrosion of Metals in Acid Solutions Containing Depolarizers. Melvin Hochberg and Cecil V. King. *J. Electrochem. Soc.*, **97**, 191-197 (1950) June.

Deals with the action of various quinones and dyes, of the phenazine, azo, triphenylmethyl, indigold and thiazine types, as corroding agents in acid solution on cadmium, tin, lead and copper. Reactions are described whose rates are diffusion, chemically, partly diffusion and partly chemically controlled and subject to inhibition by reduction products or intermediate compounds. Results are tabulated and plotted. 13 references.—BLR.

4.3, 7.1

The Effects of Sulfur in Motor Gasoline on Engine Performance. R. E. Jeffrey, J. B. Duckworth and E. J. Gay. *Petro. Proc.*, **5**, 494-497 (1950) May.

Effects of gasoline with sulfur contents of 0.25-0.30 percent on engine wear and other characteristics, as compared with fuels of 0.056-0.140 percent sulfur content, were studied in field tests involving 7 fleets of 62 vehicles covering wide sections of the country. Results showed that the influence of the high-sulfur fuels varies widely from a pronounced effect on cylinder and ring wear under certain operating conditions, to no effect under continuous operation at normal engine temperatures. Valve operation and life, muffler life and exhaust system corrosion in general were not found to be adversely affected. Little or no effect on engine varnish and sludge was noted.—BLR.

4.3, 3.4

Corrosion of Metals by Cracked Gasolines and Other Unsaturated Fuels. L. G. Gindin. *Doklady Akad. Nauk USSR*, **71**, No. 2, 361-363 (1950).

Study of corrosive action of motor fuels and oils upon metals as a function of their acidity and capacity for autoxidation. Graphs relating to corrosion of zinc, copper and lead as depending on content of actual gum-formers in various cracked gasolines. True role of peroxides in the corrosion of metals. Specific effect of metals on character of autoxidation of cracked gasolines, etc. Best methods for reducing the corrosiveness of cracked gasolines and other unsaturated fuels. (Translation available from Henry Brutcher, Box 157, Pasadena, California.)

4.3, 7.2, 7.6

TNT Into Phloroglucinol — A Staff-Industry Collaborative Report. M. L. Kastens and J. F. Kaplan. *Ind. Eng. Chem.*, **42**, No. 3, 402-413 (1950) Mar.

Centrifugal pumps which feed the concentrated sulfuric acid to the oxidizing pots are made of cast iron. Pumps between drown out and the centrifuge are of 20 chromium-24 nickel 3 molybdenum-5 manganese-1.75 copper stainless steel. Oxidation pots are made of ordinary sheet steel. Centrifuge basket is of Type 316 stainless steel.—INCO.

• Chemicals Organic

4.4, 6.5, 2.3

Corrosion of Metals by Insecticidal Solutions. G. S. Cook and N. Dickinson. *Corrosion*, **6**, No. 5, 137-139 (1950) May.

The purpose of this investigation was to determine the comparative corrosion resistance of stainless steel, copper, brass, aluminum, magnesium alloy, aluminum alloy, cold rolled steel and galvanized iron when immersed in various insecticide solutions. The eight metals were immersed in fourteen test solutions for eight weeks and periodic observations were made to determine the extent of corrosion. Weight loss and pitting, as a result of the eight-week immersion, were also determined. It is concluded that: 1. DDT in water displays a definite tendency to inibit corrosion; 2. 2-4-D inhibited corrosion on all metals tested; 3. Chlorodane is a corrosive acid insecticide; 4. Insecticides in kerosene or a fuel oil base are not corrosive; 5. The most corrosive insecticide solutions

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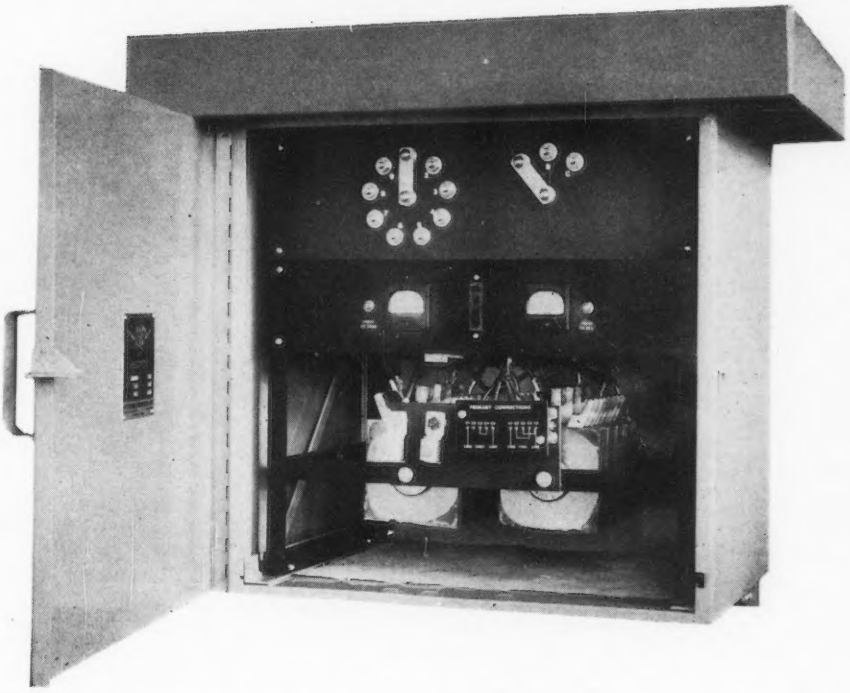

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are chlorodane in water, sodium arsenite in water, and DDT in salt water; 6. Stainless steel is the only completely corrosion-resistant metal; 7. Aluminum is of satisfactory corrosion resistance in all of the solutions except sodium arsenite. It is recommended that aluminum, aluminum alloys and Alclad, both with and without a corrosion inhibiting pretreatment such as anodizing, be investigated for their corrosion resistance to chlorodane in water, sodium arsenite in water, and DDT in salt water.—ALL.

4.4, 5.4, 8.8

Rubber and Fatty Acids. O. S. True. *Chem. Eng.*, **56,** No. 5, 263 (1949); *Rubber Res. Abs.*, **27,** No. 11, 956 (1949).

Equipment with rubber linings, but not natural soft rubber or Neoprene, can be used for fatty acids. Ebonite and mixtures of butyl rubber are suitable for the lower compounds of the series. These linings stand concentrated acids up to 71 degrees C. Fatty acids of higher mol. wt. have to be dealt with in equipment lined with flexible Hycar, which withstands concentrated acids up to about 83 degrees C. By an appropriate choice of these materials, tanks, valves and pumps can be protected against corrosion by fatty acids.—RPI.

4.4, 6.2

Reaction of Iron with Organic Sulfur Compounds. L. A. Hamilton and W. W. Woods. *Ind. Eng. Chem.*, **42,** 513-519 (1950) Mar.

In the temperature range 125 degrees to 275 degrees C, many organic compounds containing bivalent sulfur react with iron. In this reaction a major portion of the sulfur is transferred to the iron as a material which is insoluble in organic liquids and appears to be principally ferrous sulfide. This reaction is common both to corrosion problems in this temperature range and to the action of sulfur compounds as extreme pressure lubricant additives, a problem in controlled corrosion. The extent of the reactions of sulfurized terpene hydrocarbons, sulfurized sperm oil, and n-dodecyl mercaptan with iron is compared over the temperature range 100 degrees to 275 degrees C, and an attempt is made to establish a sulfur balance throughout the range. Experiments on the reaction of copper with several sulfur compounds are reported. A division of sulfur compounds into two classes, based on extreme pressure lubricant tests, is made. Within one group the rate of reaction with iron appears to correlate with effectiveness in these tests. Compounds in the second group which appear to react with iron at the same rate are quite ineffective. Two different corrosion processes appear to be involved: both of these terminate in the formation of the same iron sulfide on the iron surface. Chemical differences between the processes are not known but presumably must exist.—GPC.

• Soil

4.5, 6.5

Corrosion of Materials of Construction Underground. I. A. Denison. *Petro. Eng.*, **22,** No. 6, D5-D8; No. 8, D9-112 (1950) June, July.

Corrosion data are presented on low-alloy irons and steels, high-alloy steels, copper, copper-zinc alloys, lead and zinc exposed to soils for periods up to 14 years. The 15 soils to which the materials were exposed range from well-aerated soils deficient in soluble salts to poorly aerated soils containing high concentrations of soluble salts. The magnitude and progress of corrosion are interpreted in relation to the properties of the soils at the test sites. A comparison is made of the corrosion of iron, copper, lead and zinc in several typical soil environments. 5 references.—INCO.

• Water and Steam

4.6, 5.7

New Water Treating System Produces CO_2-Free Steam—I. Leo F. Collins and Ernest E. Dubry, The Detroit Edison Co., *Combustion*, **21,** No. 8, 47 (1950) Feb.

Feedwater treated in a zeolite-acid-degasification system produces practically carbon dioxide-free steam, an important consideration in preventing corrosion of steam condensing equipment at the 628,000 lb. per hour capacity Willis Avenue Heating Plant.

Sodium zeolite softened water goes to a specially constructed feedwater heater into which acid is proportioned before degasification by steam takes place. A 10 percent caustic solution is proportioned to water in the heater to raise effuent pH for protection of following equipment.

Part II. Ibid, March. Operating results are given.—NALCO.

4.6, 3.4

Fundamental Observations on the Significance of Oxygen in the Purification of Water and in Corrosion-Protection. L. W. Haase. *Werkstoffe u. Korrosion*, **1,** No. 1, 4-9 (1950).

The physical and chemical properties of various types of water are discussed, together with the relationships between the corrosive action of water and the degree and nature of its purification. The corrosion of metals exposed to water depends not only on the amounts of free carbon dioxide and metallic salts contained in the water, but also on its free-oxygen content. If the oxygen content is low, e.g. when organic matter is present, metal goes readily into solution; protective films form on the metal surfaces only when the amount of free oxygen present is not less than 5 mg per l. —MA.

4.6

Problems Encountered in the Treatment of Cooling Tower Water for the Prevention of Incrustation and Corrosion. E. C. Hosbach, Texas Co. *Proc. Midwest Power Conf.*, **11,** 314-17 (1949).

4.6, 3.6

The Use of Copper and Galvanized Steel in the Same Hot Water System. Building Research Station Digest No. 8, 3 pp (1949) HMSO 2d.

Notes on the use of copper and galvanized steel in the same hot water system, based largely on researches by the BNFMRA. Recommendations for means of avoiding corrosion are made.—BNF.

4.6, 7.6

Modern Trends in Industrial Water Treatment. R. C. Ulmer, E. A. Lowenthal, E. F. Drew & Co., Inc. *Oil & Gas J.*, **48,** No. 49, 92 (1950) Apr. 13.

The authors discuss boiler water treatment problems and outline solutions to them in general terms. Included are deposits (including copper and iron oxides), corrosion, boiler water carryover and selective silica carryover.

Some bases for selection between internal and external treatment are offered and tables give some information on what may be expected from various treatment methods. Decision on type of treatment should be based on the composition of the feedwater, type and operating pressure of the boiler and cost of installation and chemicals.—NALCO.

4.6, 3.5, 3.4

Corrosion Behavior in Very Dilute Aqueous Solutions. III.—Corrosion at Temperatures Below 100° C. (In German) L. W. Haase. *Werkstoffe u. Korrosion*, **1,** No. 4, 129-132 (1950) Apr.

In this part, the influence of increasing temperature on the properties of water and hence on corrosion in water from 20 degrees-100 degrees C is discussed; in particular the effect of the variation in the amount of air dissolved in the water, the electrolytic dissociation of the water and the state of the dissolved oxygen.—RPI.

4.6, 5.7

Problems of Feed Water Heating and Deaeration. A. E. Kittredge, Cochrane Corp. Paper before Midwest Power Conference, Apr. 5-7, 1950. *Proc. Midwest Power Conference*, **12,** 271-280 (1950).

A discussion of the design of a feed heating and deaerating system considering reasonable first cost, reliability and maintenance, operating efficiency and corrosion protection. The means of elimination of oxygen, carbon dioxide and ammonia used by various companies in feed water systems are outlined. A discussion of deaerating hot wells, the tray and spray deaerator are included.—INCO.

4.6, 5.7

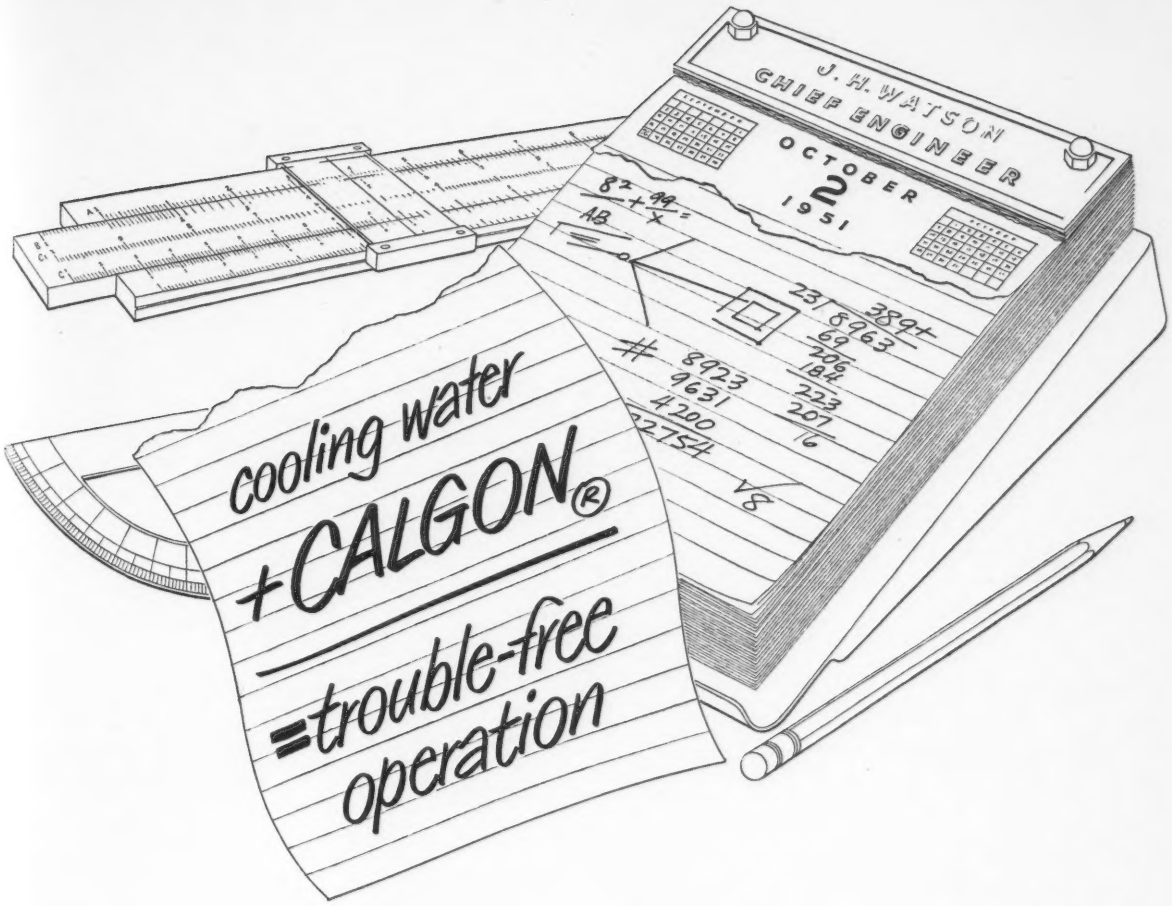
Treatment of Locomotive Feedwater. J. Leick. *Werkstoffe u. Korrosion*, 1, 64 (1950).

If water with temporary hardness used, alkalinity number of boiler water must be kept under 100. Feedwater should also show no excess alkalinity, and hardness must be equal to alkalinity. In softening by precipitation methods, no excess of chemicals should be used. Untreated water with high carbonate hardness must be decarbonated before softening by base exchange, or it should be treated by H exchange. Softening of water within boiler possible by use of phosphates, such as hexametaphosphates, for prevention of hard boiler scale. Foaming caused by increased salt content can be controlled by decantation through special valves. Oxygen corrosion avoided by proper feed-in arrangements or by addition of sodium sulfite in emergency.—EP.

4.6

pH Control Through the Use of a Sulfur Burner. Elimination of Scale and Prevention of Delignification in Cooling Towers and Similar Equipment. R. C. Ulmer and J. F. Churchill. *Petro. Ref.*, **28,** 120-122 (1949) Jan.

Millions of dollars are spent yearly in cleaning and replacing equipment in cooling vapor systems. In addition, heavy losses are sustained through heat losses occasioned by dirty heat transfer surfaces. In recent years, a better understanding has been reached regarding



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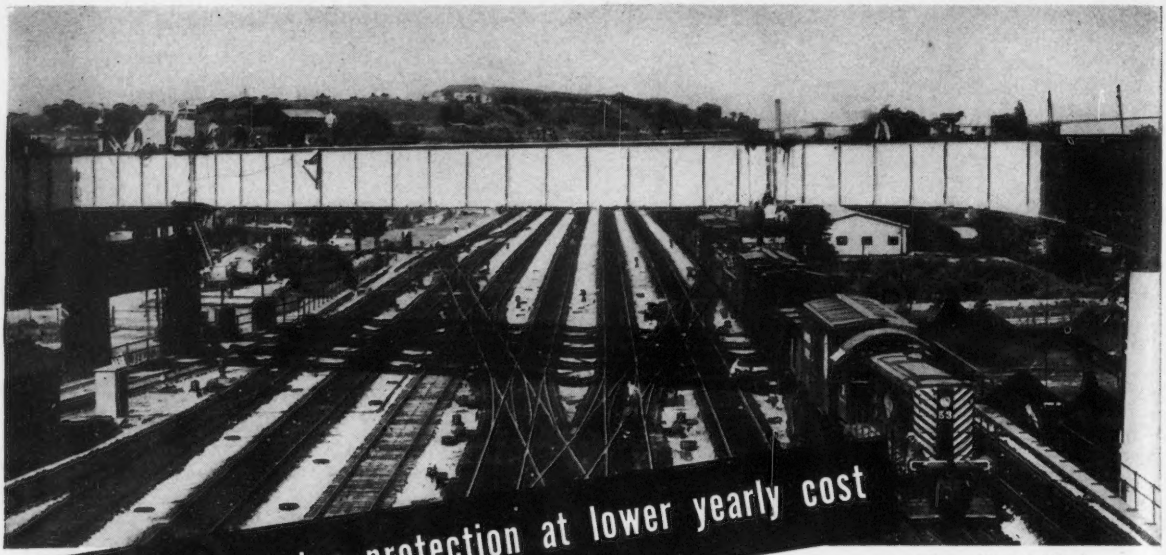

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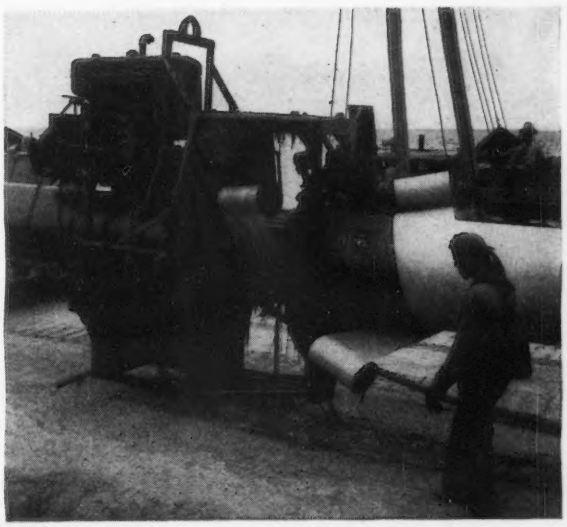

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these problems. This article reviews present information on cooling water conditioning.—GPC.

PREVENTIVE MEASURES

• Cathodic Protection

5.2, 8.4, 4.5

Planning a Corrosion Control Program. *Gas*, **26**, No. 8, 80-84 (1950) Aug.

The five papers included in this section part of a 15-part work on the value of cathodic protection which was presented at the AGA Distribution Conf. in Detroit, April 1950, consider preliminary planning. Papers presented are "Initial Steps in Organizing Program," A. D. Simpson, Jr.; "Analyze Corrosion Costs on System," C. L. Morgan; "Sell Management on Protection Economics," C. W. Beggs; "Sell Workmen on Cathodic Protection," W. R. Brough; and "Consult Operators of Underground Utilities," C. A. Erickson.

5.2

Magnesium Anodes Continue the Fight Against Underground, Underwater Corrosion. *Chem. Proc. Preview*, **13**, No. 4, 58-60 (1950) Apr.

A review of cathodic protection with emphasis on the Dow Chemical Co. anodes.

5.2

Corrosion Protection by Metallizing. J. Wakefield. *Gas Age*, **101**, 33 (1950) Mar. 16; *Gas*, **26**, No. 4, 27-30 (1951) Apr.

This article details Southern Counties Gas Co. experience in application of sprayed metal to pipe lines, holder and compressors.—GPC.

5.2, 4.6

Effect of Environment Characteristics on Cathodic Protection. F. J. LeFebvre and L. P. Sudrabin. Symposium on Cathodic Protection, Electrochem. Soc. and NACE, 185-188 (1949).

The importance of studying the analysis of the water with which the corroding metal is in contact is pointed out and practical examples of how this affects the design of the protection system are given.—MA.

• Metallic Coatings

5.3

Adhesion Strength of Electrolytic Deposits. R. Erdmann. *Eng. Dig.*, **10**, No. 4, 116-117 (1949) Apr. *Metalloberflache*, **2**, No. 5, 117-119 (1948) May-June.

Poor adhesion of electrolytic deposits can usually be traced to faulty preparation of the parent plate or deposited material. Insufficient degreasing, descaling, or rinsing, imprints of perspiring hands, hydrogen absorption and colloidal precipitates are all damaging. Alloy formation between the plate and deposit improves adhesion but usually does not occur at room temperature; one exception is the copper-plating of zinc. Subsequent heating, however, increases the alloying tendency.

Cold rolled steels are particularly suitable for bright nickel deposits. Cast iron which is to be plated should have a uniformly fine distribution of graphite and should be pickled, electrolytically degreased and scraped free of loose graphite particles. A first layer of copper plating is recommended.

In plating nonferrous metals with a metal having a very different coefficient of thermal expansion, an intermediate layer of a metal with a mean coefficient may be advantageous. On brightly polished brass surfaces, good adhesion can be obtained without further preparation. Colloidal films of proteins or their decomposition products, strongly adherent to copper, steel and nickel, may cause poor adhesion. Zinc is often copper-plated first to prevent a layer of a non-adherent ion-exchange plating from forming as a result of the solvent action of electrolytic baths. Because lead speedily forms oxide films, removal of oxide layers with nitric acid and subsequent copper-plating in a cyanide bath are recommended. Aluminum and aluminum alloys should not be plated if avoidable, since a porous plating does not keep out moisture and accelerates electrolytic destruction. If plating is needed the surface should be slightly roughened by special pickling.—PDA.

5.3, 3.5

Hard Chromium Coatings Having Maximum Wear Resistance. (Hartchrmschichten Hochster Verschleissfestigkeit). Walter Eilender, Heinz Arend and Eugen Schmidtmann. *Metalloberflache*, **3**, 57-59 (1949) Mar.

Chromium coatings of highest wear resistance have a Vickers hardness of 750-800 kg per sq mm; both harder and softer coatings are abraded more readily. This optimum wear resistance is produced by high hardness in conjunction with great toughness.

A Vickers hardness of 750-800 kg per sq mm can be obtained either by heat treatment or, preferably, by controlling the conditions of chromium deposition. When harder coatings are softened by heat, the temperature and duration of the treatment needed to reach the optimum hardness are dependent on coating thickness. Deposits produced directly in 750-800 Vickers hardness under closely controlled conditions possess the same high wear resistance of heat softened deposits. The wear resistance of very thick deposits (0.5 mm) remains essentially constant for a Vickers hardness of 750-950 kg per sq mm but decreases rapidly at lower hardness.

Abrasive wear was measured by the length, in millimeters, of the segment scooped out of a chromium plated metal sample by 1000 revolutions of an abrasive wheel bearing a load of 5 kg. The wheel was one meter in circumference, 8 mm wide and was turned at one revolution per second.

PDC Comment: The wear resistance of hard chromium coatings was studied previously by other German investigators, who found that abrasive wear decreases steadily with increasing hardness of the chromium deposit. Hard chromium produced from electrolytes containing either sulfuric or sulfuric-fluosilicic acid showed about equal wear. (Hans Wahl and Karl Gebauer, Abrasion-Testing of Hard Chromium Coatings, Metalloberflache **2**: 25-37 [1948] Feb., F-282).—PDA.

5.3, 3.4

Corrosion of Electrodeposited Nickel. L. C. Flowers and J. B. Kelley, Westinghouse Elec. Corp. *Ind. Eng. Chem.*, **42**, No. 4, 719-727 (1950) Apr.

An experimental investigation showed that nickel electrodeposits from plating baths containing salts of naphthalene disulfonic acids as brightening agents are dissolved rapidly and continuously at room temperature by distilled water through which carbon dioxide and air are bubbled. Corrosion rates range from 25 to 96 mg/sq dm/day. Electrodeposits from nickel plating baths containing no brightening agent, as examplified by Watts' nickel plate, may be pitted under these conditions but do not corrode rapidly: Neither does rolled sheet nickel. The presence of air, or probably oxygen, in the bubbling gas is shown to be of paramount importance. In terms of electrochemical theory, dissolved oxygen acts mainly as cathode depolarizer in the case of bright nickel plate and when oxygen is freely availablet the corrosion reaction is fast. In the case of sheet nickel or Watts' nickel plate, it is believed that a passive condition is produced when dissolved oxygen exceeds an undetermined limit; thus the corrosion process is stifled. No explanation can be given at this time for the lack of passivity of bright nickel plate. 14 references.—TDD.

5.3, 5.4, 5.9

Galvanized Iron and Its Treatment. *Decorator*, **49**, No. 573, 65-66 (1950).

The difficulties of painting galvanized iron are discussed. Adhesion is improved by allowing the sheeting to stand exposed to the weather for upwards of three months or by phosphatizing the surface prior to painting.—RPI.

5.3, 4.3, 4.4, 2.3

The Corrosion Resistance of Hard-Chromium Coating. H. W. Dettner. *Metalloberflache*, **4**, A33-A37 (1950) Mar.

Review of literature and report of original experiments with chromium coatings in contact with concentrated sulfuric acid, concentrated nitric acid, 25 percent formic acid, 80 percent acetic acid, artificial sea water (3 percent chloride solution), caustic potash solution (40 percent), and ammonia (10 percent). Test apparatus and technique are described.—INCO.

5.3

Fitting Hard Chromium Plating to the Job. G. C. Close. *Steel Proc.*, 36, No. 6, 281-284 (1950) June.

Describes the various physical and chemical properties of electrodeposited chromium and the value of these properties in certain industrial applications. Industrial uses of hard chromium plating are for hard surfacing production parts to increase wear, for reclaiming worn or undersize production parts, for protecting parts subjected to the corrosive effects of petroleum hydrocarbon combustion, for hard surfacing the working surfaces of drawing, stamping, forming and coining dies, for salvage of worn tooling equipment and for improvement and maintenance of many types of metal cutting tools. Its properties include extreme hardness and wear resistance, abrasion resistance, low coefficient of friction, non-seizure properties, oxidation resistance and corrosion resistance. Comparisons of various coefficients of friction between different metals are given.—INCO.

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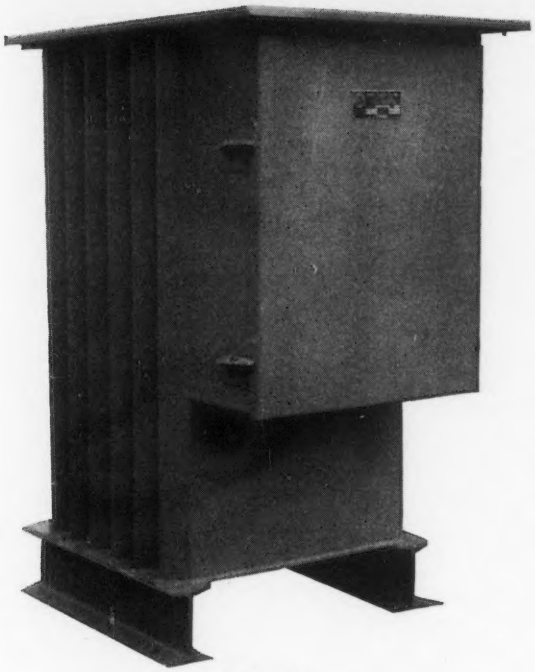

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5.3

Protection of Surfaces Against High-Temperature Corrosion. *Eng. Boiler House Rev.,* **65,** No. 13 (1950); *J. Brit. Shipbuilding,* **5,** No. 4, 245 (1950).

The advantages of aluminum coatings for the protection of iron and steel surfaces against the various kinds of corrosion encountered in steam engineering practice are discussed. The metal may be applied by spray gun in powder form or in the molten state. It may also be applied by dipping or by the colorizing process. A brief reference is made to the proposed use of a stoved lacquer containing aluminum powder.—RPI.

5.3, 5.4, 2.3

Tin as Undercoat for Paint. *Ind. Fin.,* Brit., **2,** No. 15, ix-xvi (1949); cf. *Review,* 64, (1946).

Color photographs of models and exposure panels after periods of natural or accelerated weathering demonstrate the value of thin (0.00005-inch) tin undercoats which were apparently more corrosion-resistant than phosphate coatings. On unpainted steel thicker coatings (0.0005-inch) of an 80 percent tin/20 percent zinc alloy were effective in preventing corrosion during salt-spray tests. —RPI.

5.3

Protection of Metals by Chromium Diffusion. *Chem. & Ind.,* No. 24, 448 (1950) June 17.

The Office National d'Etudes et de Recherches aeronautiques, France, has perfected a simple method of chromizing metals by gaseous cementation. Articles are heated in contact with the cement of powdered chromium or ferro chromium, aluminum or kaolin and an ammonium halide. Nascent chromium diffuses into the interior of the metal. With a mild steel, 0.1 carbon, diffusion layers have a chromium content exceeding 50 percent at the surface and decreasing towards the interior. The layers are perfectly bonded and bright when ammonium fluoride is used. Their effective thickness is 0.1 mm after 3 hours at 1000 degrees C and 0.25 mm after 6 hours at 1100 degrees C. They are resistant to nitric acid, dry oxidation, corrosion by combustion gases, and thermal shock up to 900 degrees C.—INCO.

5.3, 5.9, 6.4

Plating on Aluminum Alloys. *Die Castings,* **7,** No. 10, 47-51 (1949).

The various factors which affect the preparation and plating of aluminum alloys are briefly discussed and practical cleaning methods are described. A method of checking the adherence of the plate is given and references are made to alkali cleaners.—MA.

5.3

Improved Plating and Corrosion Protection. *Steel,* **125,** No. 21, 82-85+ (1949) Nov. 21.—MI.

5.3

Metal Plating from Carbonyl Gases. *Chem. Eng.,* **56,** No. 10, 118-119 (1949).

The gas-plating process is described briefly and its advantages and disadvantages discussed. While chiefly used for nickel, the process is also applicable to iron, chromium, tungsten and molybdenum. Compared with electroplating, the process gives better reproduction of irregular surfaces and is suitable for application to non-conductors.—MA.

5.3, 4.2

Automatic Spraying—Metallic Protection of Constructional Steelwork. *Iron and Steel,* **22,** No. 4, 121-123 (1949) Apr. —MI.

5.3

Aluminum Dipping Process. *Eng. and Boiler House Rev.,* **65,** 13-15+ (1950) Jan.

The aluminum process is primarily applied for the purpose of the scaling of steel at moderately high temperatures. In this process the iron or steel surfaces are immersed in a bath of molten aluminum. The penetration of the aluminum into the iron as required for the achievement of an adherent coating will take place only if the iron surface has been completely freed from oxides. Moreover, the surface of the aluminum bath must also be free from an oxide layer, as such a layer would keep the liquid aluminum from coming into contact with the surface of the metal to be treated; and it is this requirement which makes the practical application of the liquid bath process most difficult. Immersion of the work surface in a molten salt bath has been found to provide an effective method for cleaning the surface of the work prior to the dipping process and various salt bath compositions have been proposed. In the Dellgren process the access of atmospheric oxygen at any stage of the aluminum dipping process is prevented by special means. Thus a protective atmosphere is provided during the preliminary salt bath treatment, during the transfer of the work piece into the bath and also during the cooling process. The protective atmosphere may be either hydrogen or towns gas. In the treatment of steel tubing, an aluminum layer of some 0.0025 inch thickness is, it is reported, produced and the brittleness of the aluminum layer can be minimized in this process by employing an aluminum bath containing small additions of zinc. A relatively recent process is the Moeller process, in which the bath of molten aluminum is carried on top of a layer of molten salts, the liquid aluminum floating on top of the heavier salt bath. The process is carried out by first immersing the article to be coated in the bottom layer of molten salt for the purpose of deoxidizing the surface and heating the article to proper process temperature. After that, the article is raised into the layer of molten aluminum where the surface receives its coat of aluminum.

5.3, 6.2

Bonding Aluminum to Ferrous Alloys. M. V. Little, Fairchild Engine and Airplane Corp. *Machinery,* **56,** No. 12, 173-177 (1950) Aug.

Details and applications of the "Al-Fin" process in which pure aluminum and its alloys can be molecularly bonded to iron and steel are given. The process was originally developed for molecularly bonding a finned aluminum muff to the thin-walled steel cylinder liner in the Ranger aircraft engine. The "Al-Fin"

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Sworn to and subscribed before me this 26 day of September, 1951.

(seal) Ann Graham

(My commission expires June 1, 1953)

process consists essentially of casting molten aluminum alloy around a specially prepared surface of the ferrous liner or insert. Suitably cleaned ferrous components are then immersed in a bath of molten aluminum. A battery of Hevi-Duty electrically heated furnaces is employed for melting the aluminum. The temperature of the furnaces is maintained at from 1200 degrees to 1450 degrees F, depending on the melting point of the aluminum alloy being used. When the ferrous part reaches the temperature of the bath, the iron reacts with the molten aluminum-iron alloy on the cleaned surface of the part. Photomicrographs of the intermetallic bond formed between various types of ferrous metals and aluminum, at a magnification of about 250, are shown. In tests conducted on aluminum-steel bimetallic samples, the tensile strength of the bond in tension ranged from 11,000 to 17,500 psi.—TDD.

5.3. 6.4

Conditioning Aluminum Alloys for Electroplating. Fred Keller and Walter G. Zelley. *J. Electrochem. Soc.*, **97**, 143-151 (1950) Apr.

Various conditioning treatments are described. Manner in which the treatments and variations in the zinc immersion layer may affect the performance of plated aluminum alloys is described.—BLR.

5.3, 1.3

A Survey of the Metal-Spraying Industry Using the Wire Process. Donald E. Harris. *Australasian Engr.*, **1950,** Apr. 52-55.

Zinc coatings are recommended for protection in conditions of ordinary and marine-atmosphere exposure, and also for immersion in hard waters and in seawater. Sprayed aluminum coatings are being used for the treatment of tanks for the storage of soft water and edible oils and for protecting gas burners, hot plates and electric furnace equipment against corrosion at high temperature. Tin coatings, which are expensive, are used in the food industry. Lead coatings have only a few uses in the chemical industries and copper, bronze, and brass have a limited application for decorative finishes.—MA.

5.3

The Properties of Thick Sprayed Coatings. J. Grilliat. Part of thesis for diploma at Conservatoire National des Arts et Metiers. *Metaux et Industries*, No. 1, 14-23 (1950).

Data on mechanical, electrical, physical and corrosion-resiting properties of a number of sprayed coatings, including 18-8.—INCO.

5.3, 1.3, 6.4

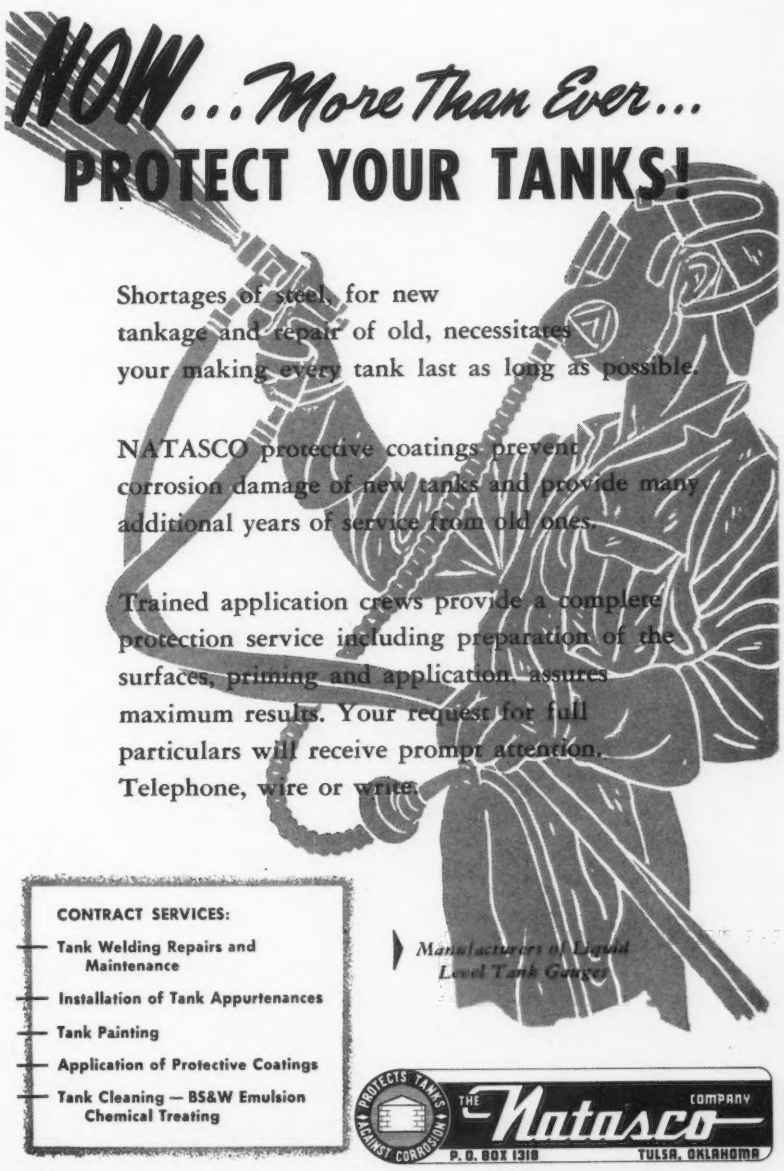
Metal Coatings Formed by Methods Other Than Electrodeposition. B. W. Gonser. *Prod. Fin.*, **14,** No. 8, pages 58 + (1950) May.

This review article outlines the processes of hot dipping, vapor-phase deposition, vacuum evaporation and spraying metal coatings. The oldest process, hot dipping, is used extensively for depositing aluminum and zinc coatings. Aluminized steel, which has excellent corrosion resistance, heat resistance and heat reflectivity, makes it very suitable for applications in furnaces, electric stoves, automotive mufflers and tail pipes. A recent development is the coating of steel wire with aluminum. P. T. Stroup and G. A. Purdy of the Aluminum Company of America report that the chief considerations in the process are the temperature of the aluminum coating bath and control of the formation of the iron-aluminum compound on the surface, one of the most effective controls being the addition of silicon to the bath. In a typical process the aluminum silicon alloy bath is maintained at about 1250 degrees F (676 degrees C) and the flux at 700 degrees F (371 degrees C). Coatings of the refractory metals to withstand elevated temperatures are usually deposited by vapor-phase methods. Vacuum evaporation is an economical method of depositing thin coatings of great brilliance. Aluminum coatings deposited by this method on glass and plastic surfaces will reflect over 80 percent of the incident light. Metal spraying has the advantage of forming coatings very quickly, the ability to coat large structures and to apply thick coatings to a limited area. Sprayed aluminum coatings are used primarily for their excellent corrosion protection. —ALL.

5.3, 6.5

New Method for Thermal Chromizing and Formation of Diffusion Alloys. P. Galmiche. *Rev. Met.*, **47,** 192-200 (1950) Mar.

Features of chromizing original experiments on chromizing of 0.1 and 0.4 carbon steels, properties of the coatings produced hardness, corrosion-resistance,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preliminary decarbonization of high-carbon steels prior to chromizing, nitriding of chromized surfaces, chromizing of non-ferrous metals and alloys, and formation of alloy layers by diffusion, e.g. chromium-aluminum or chromium-aluminium-silicon are discussed.—INCO.

5.3, 4.1, 3.5

A New Thermal Chromizing Process and the Formation of Mixed Alloys by Diffusion. P. Galmiche. *Recherche Aeronaut.*, **14**, 55-63 (1950).

The diffusion layer produced on steel surfaces by chromizing has a high chromium content and thus confers high resistance to nitric acid or marine corrosion, elevated temperature, and wear. The various processes are briefly discussed and a new chromizing method is described. This consists of reaction in the gaseous phase using the vapor pressure of a chromium halide (usually the fluoride, as the chloride is hygroscopic) formed by heating a mixture of 30-60 percent powdered chromium, 3-10 percent ammonium fluoride, and 40-60 percent of a diluent such as alumina, magnesia, or kaolin. The part to be treated is placed between the above mixture and a container of powdered chromium; and heated in a hydrogen atmosphere. Experiments using 0.1 and 0.4 percent carbon steels, as well as cast iron (2.9 percent carbon) are described; they showed that whereas the coatings produced on the lowest-carbon steel were uniform and as bright as electrodeposited chromium, those on the remainder were duller. Further, taking the effective chromium content of the layer to be > 13 percent, 3-hour treatment at 1000 degrees C produced 0.1 mm effective layer on the 0.1 percent carbon material, whereas 6 hours at 1100 degrees C gave a thickness of 0.25 mm. Lesser values than these are produced on the 0.4 percent carbon steel and cast iron. The chemical composition, structure, hardness and corrosion- and heat-resistance of the diffusion layer were investigated. Some details are given for the treatment of high-carbon steels, non-ferrous metals and alloys, and the formation of mixed-alloy diffusion layers. Silicon, ferro-silicon, or silicon carbide additions to the mixture produces a chrome-silicon layer; aluminum, ferro-aluminum, or aluminum carbide produce a chrome-aluminum coatings. 16 references.—MA.

• Non-Metallic Coatings and Paint

5.4

New Primer "Kills" Rust. *Pipe Line News*, **32** (1950) June.

A new liquid primer called R-10-X contains Se which combines with ferric oxide to form an extremely hard, dense substance that is impervious to moisture and holds paint perfectly. The R-10-X penetrates into the metal pores and neutralizes all the rust. R-10-X can be applied directly to rusted surfaces without cleaning. Mfd. by Thompson-Long Co. —INCO.

5.4

Acid-Hardening Paints and Varnishes Based on Alkyd and Urea Resins. F. J. Hermann and A. A. C. De Gee. CIMO Afd. Verf, Circ. 59, 29 pp. (1949).

A series of varnishes and enamels has been prepared based on mixtures (5:2, 4:2, 3:2) of alkyd resin (castor or linseed oil modified types) and urea resin, incorporating as hardner for the latter a 20 percent alcoholic solution of 4 moles hydrochloric acid to 1 mole boric acid (1, 2½ or 5 percent urea resin solution). Pigments used for the enamels were synthetic red ferric oxide and extended to titanium dioxide or barium sulfate (50 percent). These varnishes and enamels were compared with a similar series stoved without acid hardener and others based on stoving and air-drying alkyd resins only and N.C. For the varnishes a hardener addition of about 2½ percent seemed the optimum. 5 percent gave too low a can stability and one percent too slow a drying speed. Can stability was increased by extra thinning of the varnish and with 2½ percent hardener could be increased to > 5 hr. with a drying time of 3-4 hours. The first coat being dry to touch, a second could be applied without lifting the undercoat. As compared with the stoved products the acid-hardened products showed poor flexibility (of the enamels) (Erichsen test) after indoor ageing, equal or rather longer hardness (scratch or pendulum test), less water-resistance, equal color retention, and gloss (of the enamels) which was better initially but poorer after indoor ageing. Cold-check resistance of the acid-hardened varnishes (at 50—12 degrees) was good but some of the varnishes were deficient in resistance to ethyl alcohol and aqueous sodium carbonate. On outdoor exposure on oak

panels all varnishes (including air dried alkyd) showed blistering after nine months. After one year the gloss of the acid-hardened varnishes was equal or superior to the gloss of the air-dried alkyds. On stainless steel panels the order of merit of the varnishes was air-dried alkyd, better than acid-hardened urea/alkyd, slightly better than stoved urea/alkyd. After one year acid-hardened ferric oxide enamels showed less gloss than the corresponding stoved enamels. All titanium dioxide enamels chalked after three months. It was concluded that it is possible to prepare acid-hardened urea/alkyd varnishes to meet normal requirements but no outstanding properties are apparent.—RPI.

5.4, 6.4

On the Preparation of Hard Oxide Films with Precisely Controlled Thickness on Evaporated Aluminum Mirrors. Georg Hass, U. S. Engineer Center, Fort Belvoir, Va. *J. Optical Soc. Am.*, 39, 532-540 diagrs. (1949) July.

Increasing the thickness of the natural oxide finish on evaporated aluminum mirrors gives increased surface protection. Precise control of thickness can be obtained by anodic oxidation in electrolytes such as ammonium tartrate. The films produced are amorphous, free of pores, and have excellent abrasion resistance. They are, however, more sensitive to boiling water and salt spray than silicon monoxide coatings. They show no noticeable absorption of ultraviolet, visible, or infrared radiation. Their refractive index varies from 1.67 at 3000 Å to 1.62 at 6000 Å. Highest reflectivity in the visible range is obtained by anodizing for 2 minutes at 120 v.

The thickness formed in a given time increases linearly with the applied voltage and amounts to 7.5 Å per v per minute. In 3 percent ammonium tartrate the current efficiency is about 80 percent although even after 65 hours no solvent effect on aluminum oxide could be measured. The thickness of the oxide is 1.38 times that of the aluminum layer replaced. Thickness of a pure aluminum film can be determined by the voltage required for complete oxidation.

Heat treatment in air is not a practicable method of preparing these coatings since a temperature of more than 400 degrees C is required and the resultant films are rough and nonuniform.

Anodically coated mirrors are suitable for preparing reflection type interference filters. A filter with a coating 50 Å thick reduces reflectivity of visible light to less than 2 percent but exhibits high reflectance in the ultraviolet and infrared spectral ranges.—PDA.

5.4, 3.5

Finish to Resist Water Impingement Erosion on Leading Edges of 700-mile-an-hour Airplanes Sought by Navy Department Bureau of Aeronautics. A. C. Goetz. *Corrosion*, **6**, No. 6 (1950) June, NACE News Section, 16, +.

5.4

Notes on the Formulation of Industrial Finishes for Metal. M. A. Glaser. *Paint, Oil Chem. Rev.*, **113**, No. 8, 37-38+ (1950).

The selection of vehicles for the production of special properties in a finish is considered. The formulation of a white high-reflecting stoving paint, clear finishes for exterior use, a high-temperature resistant non-yellowing enamel and a silicone finish are discussed.—RPI.

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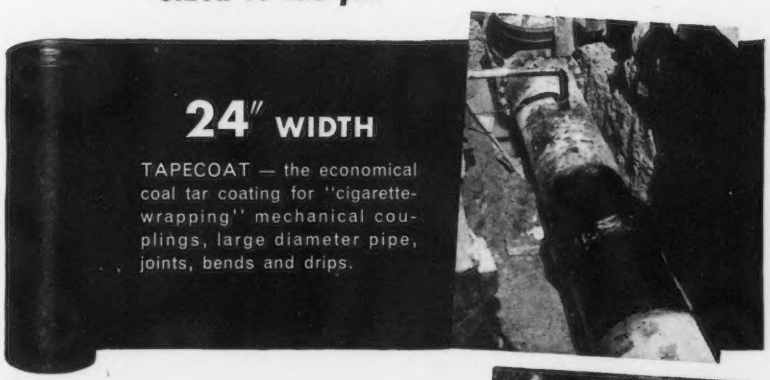

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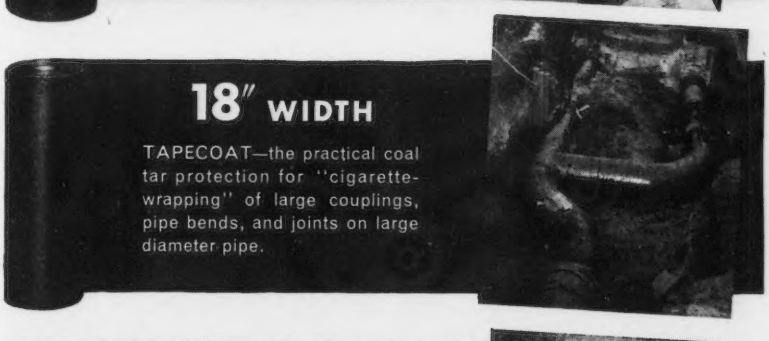

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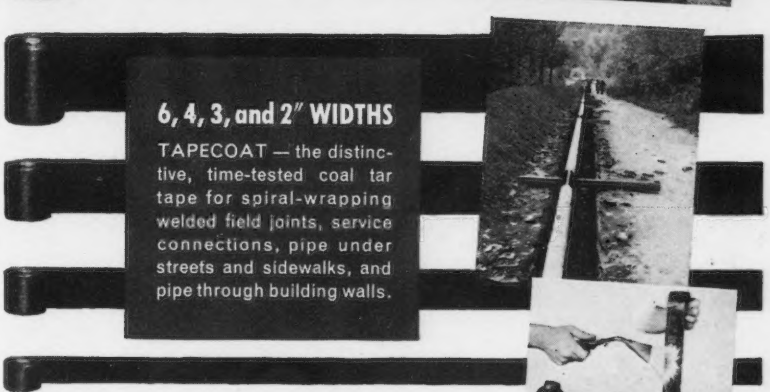

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5.4, 1.6

Protective Coatings for Metals. J. W. Gailer and E. J. Vaughan. 9 x 6½ in. Pp. xiv + 261. illustrated. 1950. London: Charles Griffin and Co., Ltd. (24s. net).

This book is primarily intended to assist those concerned with the selection or inspection of protective coatings on metal articles. About one-third of the book deals with metallic coatings produced by electroplating, hot dipping, cementation, or metal spraying, while a further third deals with non-metallic coatings — phosphate, black oxide on steel, anodized and chemical coatings on light alloys, chromate films on zinc, paints, lacquers and enamels, as well as temporary protectives. Except for a short general introduction to electroplating, each type of coating is dealt with separately. First, brief but precisely detailed descriptions of the method of application are given. These are well chosen to give the buyer or inspector an appreciation of the process employed, but the very precision of the details perhaps involves a danger of their being used as full operating instructions, for which they are hardly suited. Then follows a list of all the appropriate test methods for the coating, in which any specific tests and any special variations of more general tests are fully detailed. Full descriptions of these more general tests, which are common to large classes of coatings, are collected together in eleven appendices which thus comprise a considerable and important section of the book. This scheme necessitates, however, a somewhat confusing system of cross-references.

Finally, 26 pages are devoted to summary tables which set out the uses, properties, methods of application, and inspection of all the coatings considered. The conciseness of these tables should make them especially valuable to designers and planning engineers.

Many references to the literature are given which allows the much condensed information to be amplified. It is, however, to be regretted that in general reference is made to abridged accounts in the technical press rather than to original publications. This is particularly noticeable as regards information originally published in the *J. Electrodepositors' Tech. Soc.*, a publication now very generally available.

The information given is accurate and precise; the range covered is wider than in most recent books on metal finishing. The treatment of the important jet test for the thickness of electrodeposited coatings, however, does less than justice to the standardization achieved in this country. Indeed the name "BNF Jet Test" and the now familiar diagram are omitted in favor of modifications which, whatever their merits, are far less known and considerably more complicated. The methods quoted on pp 51-55 for obtaining thick adherent electrodeposits of nickel on various metals are also unwisely included, since their original context made it clear that they were intended for engineering applications and not for protective coatings.—MA.

5.4, 1.3

Anti-Rust Paints in Building. P. Freitag. *Trav. Peint,* **4,** No. ii bis (Special No.), 35 (1949).

A brief review of the history and present use of such paints.—RPI.

5.4, 1.3

Anti-Corrosive Paints. A foulon. *Farbe u. Lack.*, **55,** No. 6, 195-197 (1949).

A review of the latest developments in protective coatings methods.—RPI.

• Inhibitors and Passivators

5.8, 5.9

Effect of Inhibitors on the Acid Pickling of Steel. Part I. (In Polish) M. Smialowski and J. Foryst. *Prace Badawcze Glownego Instytutu Metalurgii i Odlewnictwa,* **1,** No. 2, 147-153 (1949).

Experiments were made to determine the inhibition efficiency of dibenzylsulfide, dibenzylsulfoxide and thiocarbanilide in the acid pickling of iron, steel, and other metals. Results show that the action of inhibitors is more chemisorption than pure physical sorption, and that this phenomenon is related to the ability of some metals (particularly nickel, cobalt, and iron) to become passive. 11 references.—BLR.

5.8, 5.9

Synthetic Surface-Active Agents in Metal Finishing. Georgia Leffingwell. *Metal Fin.*, **47,** No. 4, 68-70 (1949) Apr.

Among the many applications of synthetic surface-active agents are their uses 1) in electroplating processes and pickling solutions, 2) as combined metal cutting and grinding lubricants, 3) as anticorrosives and 4) as metal cleaners.

In electroplating and wire pickling baths, the chief function of synthetic additives such as alkyl aryl sodium sulfonates, sodium alkyl sulfates, or octyl alcohol sulfates, is to lower the surface tension and permit complete contact between the metal and the electrolyte. Additives in pickling solutions also retard the attack of the acid on clean metal areas. The reduction in metal loss and amount of acid required may defray the cost of the synthetic and make worth while the slightly increased pickling time which may be required. A decrease in hydrogen embrittlement is also reported as an advantage of using the synthetic.

New amine and sodium salts of oxygenated hydrocarbons serve as metal cutting and grinding lubricants and as rust preventives.

A series of substituted oxazoline amine-type compounds which can be utilized in preventing corrosion are nonvolatile cationic surface-active agents with acid-accepting properties. Most of the salts of the series are at least somewhat oil soluble, and small proportions of the product can therefore be used in oils to tie up traces of acid which may develop from either the deterioration of the oil itself or of other additives or from deposited perspiration.

These oxazoline amine-type compounds, an alkyl naphthalene sulfonate and certain sodium alkyl sulfates are among the surface-active agents useful in metal cleaning.—PDA.

5.8, 5.9

Effects of Inhibitors on the Acid Pickling of Steel. Part II. (In Polish) M. Smialowski, J. Synowiec and M. Szota. *Prace Badawcze Glownego Instytutu Metalurgii i Odlewnictwa,* **2,** No. 1, 31-35 (1950).

Ten kinds of structural steel were investigated with respect to inhibition efficiency of dibenzylsulfide in sulfuric acid at 40 degrees C. Results could not be satisfactorily correlated. Further experiments were made on mixtures of electrolytic iron powder with 2 percent nickel or copper powder added. Rate of hydrogen evolution from 2 Normal sulfuric acid solution was investigated as function of time and inhibitor added. Adsorption of aniline and diphenylamine (weak sulfuric acid inhibitors) on electrolytic iron powder was then studied. Shows how amount absorbed can be accurately determined colorimetrically. Data are charted.—BLR.

MATERIALS OF CONSTRUCTION

• Ferrous Metals and Alloys

6.2, 5.9

Surface Finishing Stainless Steel. L. F. Spencer. *Iron Age,* **165,** No. 10, 73-77; No. 11, 82-85 (1950) Mar. 9, 16.—MI.

• Non-Ferrous Metals & Alloys—Heavy

6.3

Engineering Possibilities of Tantalum. J. F. Stirling. *Pract. Eng.*, **20,** No. 517, 709-711 (1949).

The discovery and development of tantalum are described. The physical and chemical properties are surveyed, and its uses in surgery, electrical engineering an the chemical industry are detailed. A tantalum-tungsten alloy is described.—MI.

6.3, 3.5

Oxidation of Cobalt at High Temperatures. (In French) Gabriel Valensi. *Met. Ital.*, **42,** 77-84 (1950) Mar.

Theoretical analysis of the problem is supplemented by a critical correlation of literature data and a description of some experimental work. While freshly exposed cobalt does not follow the Philling and Bedworth ordinary law under 900 C, but a more complicated one, cobalt exposed to air, becoming covered by an invisible film, has a high-temperature oxidation rate which complies with the ordinary parabolic law. This same law is followed over 900 C, but there are two activation energies.—BLR.

6.3, 4.3

Corrosion Resistance of Tantalum-Molybdenum Alloys. Walter C. Schumb, Schrade F. Radtke, and Michael B. Bever. *Ind. Eng. Chem.*, **42,** 826-829 (1950) May.

A series of the above alloys from 0 to 100 atomic percent tantalum in 10 atomic percent steps was prepared by arc fusion of sintered compacts in an argon atmosphere. Resulting ingots were accurately cut, ground and polished and the surface of each sample estimated. Density, hardness and other properties were determined. Corrosion resistance at 50 degrees C in solutions of concentrated hydrochloric acid, nitric acid and sulfuric acid was determined. Tantalum-rich specimens were found to be unattacked, whereas the molybdenum-rich alloys were attacked at increasing rate in the order sulfuric acid, hydrochloric acid, nitric acid.—BLR.

INDEX TO ADVERTISERS

Vol. 7 November, 1951 No. 11

	Page
Amercoat Corp.	Inside Front Cover
American Brass Company	23
American Cast Iron Pipe Co.	6
American Smelting & Refining Co., Federated Metals Division	i
Atlas Mineral Products Co.	26
Barrett Division, Allied Chemical & Dye Corp.	17
Bauer & Black, Polyken Industrial Tape Div.	Inside Back Cover
Bechtel Corp. & H. C. Price	13
Brance-Krachy Co.	43
Calgon, Inc.	39
Carey, Philip Mfg. Co.	41
Cathodic Protection Service	15
Cathodic Servicing Co.	37
Corrosion Directory	25
Corrosion Engineering Co.	20
Day, S. D., Co.	24
Dixie Tank & Bridge Co.	20
Dowell, Inc.	ii
Earl Paint Corp.	viii
Electro Rust-Proofing Corp.	22
Gerrard & Co.	18
Glass Fibers, Inc.	ix
Good-All Electric Mfg. Co.	ii
Harco Corporation	9
Harper, H. M., Co.	18
Hill, Hubbell & Company, Division of General Paint Company	50
International Nickel Co., Inc.	xii
Johns-Manville Co.	21
Koppers Co., Inc.	7
Mayes Bros.	xiii
Metco System Contractors	40
Michigan Pipe Company	14
Minnesota Mining & Mfg. Co.	33
Mutual Chemical Co.	32
Natasco Co.	45
National Association of Corrosion Engrs.	14, 16
National Carbon Company, Union Carbide & Carbon Corp.	408
Nicolet Industries, Inc. (Formerly Gama Industries, Inc.)	46
Owens-Corning Fiberglas	vi, vii
Pipe Line Service Co.	35
Pittsburgh Coke & Chemical Co.	8
Plastic Engineering Sales Corp.	34
Positions Available	44
Reilly Tar & Chemical Corp.	5
Royston Laboratories, Inc.	10
Rust-Oleum Corp.	19
Service Engineers, Inc.	28
Standard Magnesium Corporation	12
Standard Pipeprotection, Inc.	31
D. E. Stearns Co.	Back-Cover
Tapecoat Co., The	47
United States Stoneware Co.	xi
Williamson, T. D., Inc.	49

• Non-Ferrous Metals & Alloys—Light

6.4, 5.9

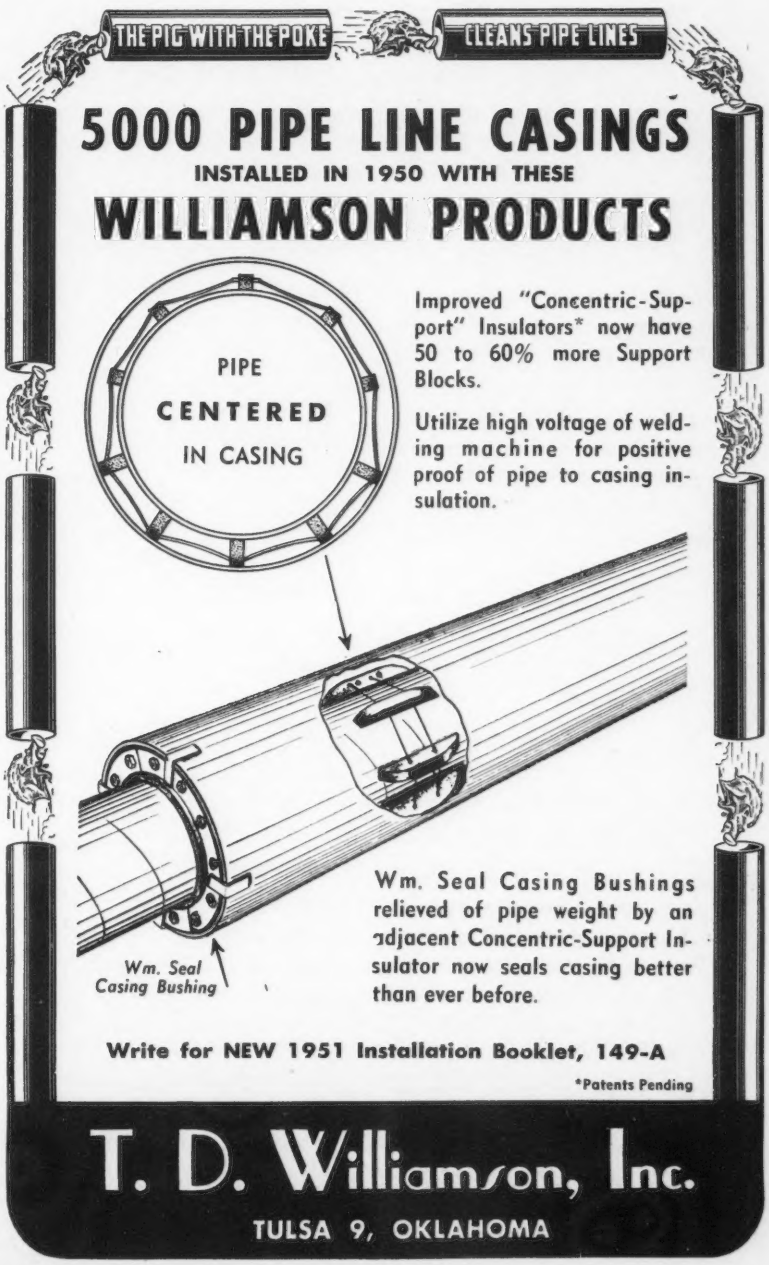
Methods for the Protection and Decoration of Aluminum. V. F. Henley. *Electroplating*, **3**, No. 7, 248-252 (1950) Mar.

Emery bobbing; polishing; removal of effects of local overheating; cleaning; chemical bright dipping; electrobrightening and electropolishing; anodizing; dyeing; and chemical oxidation processes.—BNF.

6.4

Performance of Aluminum Alloys in Marine Environments. C. J. Walton and E. T. Englehart, Paper presented at a meeting of the Society of Naval Architects and Marine Engineers, Chesapeake Section 30th November 1949. *Light Metals Bull.* (England) **12**, No. 7, 281 (1950) Mar. 31.

The authors review the applications of aluminum alloys in the marine field, including hulls, superstructures on vessels with steel hulls and tanks for transporting chemical. The use of these alloys has been justified on the basis of their light weight and high resistance to corrosion, which results in vessels with better stability and lower maintenance costs. A number of exposure tests carried out in sea and harbor waters on various aluminum alloys are described and the results tabulated. Experiments on protective coatings demonstrated the importance of the use of a zinc chromate primer, and the deleterious effects of lead-pigmented primers. The best paint performance was obtained when the surfaces had been either lightly sandbasted or chemically cleaned with a proprietary phosphoric acid compound. The prevention of faying surface corrosion and the use of sprayed-metal coatings was also investigated; and tests were carried out on an aluminum-alloy deck-plate assembly exposed to a sea salt solution and to a sea-coast atmosphere. Service conditions were simulated in experiments on the center hull section of a high-speed 100-foot patrol boat constructed in scaled down dimensions. The question of galvanic corrosion is discussed briefly and the necessary precautions which should be taken to avoid it in marine applications are detailed. A bibliography is given.—ALL.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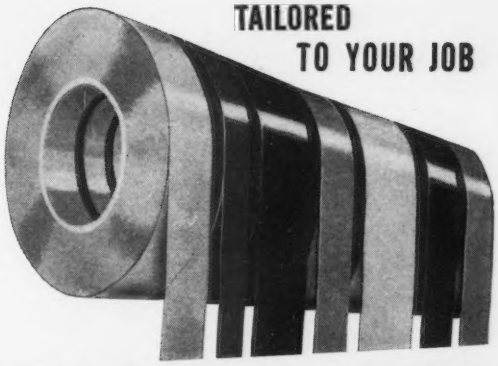

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